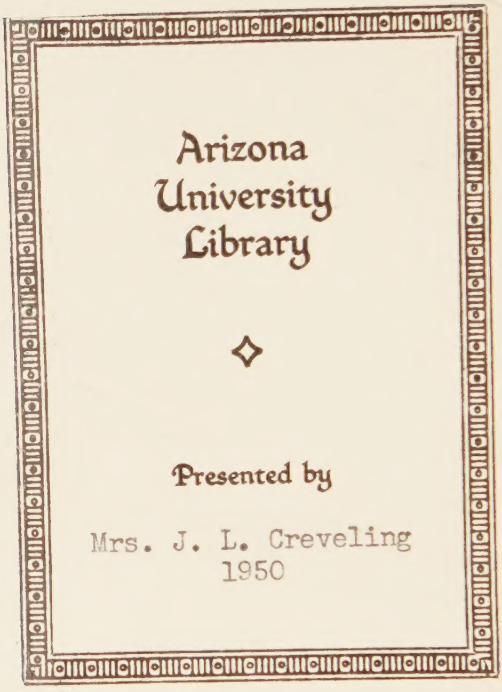

Arizona
University
Library
Presented by
Mrs. J. L. Creveling
1950

Digitized by the Internet Archive
in 2025

https://archive.org/details/bwb_S0-ELD-006

CAR LIGHTING BY ELECTRICITY

A Practical Treatise on the Construction, Operation, Inspection and Maintenance of the Car Lighting Systems in Use on American Railway Cars

By

CHARLES W. T. STUART

FOREMAN OF CAR LIGHTING, PHILADELPHIA TERMINAL, PENNSYLVANIA RAILROAD

PUBLISHED AND PRINTED IN U. S. A.

BY

SIMMONS-BOARDMAN PUBLISHING COMPANY

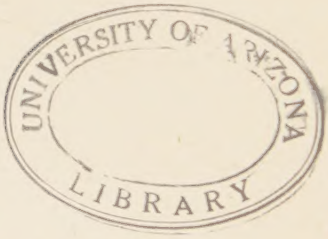
30 CHURCH STREET, NEW YORK, N. Y.

CLEVELAND, OHIO. CINCINNATI, OHIO. NEW ORLEANS, LA.

CHICAGO, ILL. WASHINGTON, D. C.

34 VICTORIA STREET, WESTMINSTER, LONDON, S. W. I, ENGLAND.

Copyright,
Simmons-Boardman Publishing Company
1923



625.22
S92c

PREFACE

To meet the need of the practical man as well as the engineer and the student, the writer has endeavored to make this book a practical treatise on the subject of "Car Lighting by Electricity" as now in general use on American railways. The use of oil and gas for car lighting has been superseded to a very great extent by electric equipment, and it therefore is essential that those engaged with the construction, operation, inspection and maintenance of car lighting equipment have available a practical discussion of the subject couched in language intelligible to the average non-technical reader. It has been the aim of the writer to present the various phases of car lighting in a manner so that the practical worker in the field, the engineer, or the student may find a comprehensive presentation of such phases of the subject as may have a direct interest for him, or that may, in a general way, assist in the betterment of the art of car lighting.

A large part of the text was obtained from a series of articles written by the author and published in the *Railway Electrical Engineer*. Other data was obtained from the manufacturers of car lighting equipment.

The writer desires to express his sincere appreciation of the assistance given by many of the electrical engineers connected with railway and car lighting companies. Among those who gave valuable advice and assisted in the preparation of many of the articles making up the book, are: E. E. Godard, Pennsylvania Railroad; J. L. Woodbridge, Electric Storage Battery Company; W. F. Bouche, Gould Coupler Company; W. L. Garland and J. L. Marsh, Safety Car Heating & Lighting Company; C. E. Walker, Stone-Franklin Company; W. L. Bliss and O. R. Hildebrandt, United States Light and Heat Corporation.

The present stage of development of direct-drive equipment

212833

for the axle generator system of car lighting is described briefly, and there are also appended the specifications covering the car lighting Standards and Recommended Practices of the American Railway Association.

CHARLES W. T. STUART.

Philadelphia, Pa.
July, 1923.

CONTENTS

CHAPTER I

PAGE

THE HISTORY OF CAR LIGHTING.—The First Attempts at Car Lighting by Electricity; Storage Battery System; Head-End System; Axle Generator System; Straight-Storage System; The Use of Storage Batteries in America 1–6

CHAPTER II

THE STRAIGHT STORAGE SYSTEM.—Increasing Battery Storage Capacity for Special Cars; Lighting from One Set While the Other Set Charges; Advantages and Disadvantages of the Straight Storage System 7–16

CHAPTER III

HEAD-END SYSTEM.—The Train Line; Method of Connecting Train Line Wires; Arrangement of Head-End Systems—Generator in Baggage Car; On Locomotive; Battery-Charge Diagrams 17–24

CHAPTER IV

AXLE GENERATOR SYSTEM.—Car Lighting Generators; Direction of Rotation; Magnet Frame; Housing Heads; Poles; Field Coils and Retainers; Armature; Brushes and Brush Holders; Pole Changer 25–33

CHAPTER V

REGULATING APPARATUS FOR AXLE GENERATOR SYSTEMS.—Generator Regulator; Total Current Regulation; Battery Charge Regulation; Regulator Parts; Lamp Regulator; Wiring Diagram; Flow of Current 34–44

CHAPTER VI

TRANSMISSION OF THE AXLE GENERATOR.—Belt Drive; Pulleys; Belt Fasteners—Crescent, Alligator, Jackson, Walker; Belt Tension; Generator Suspensions—Truck, Body; Arrangements for Lining-Up the Generator; Comparison of Generators; Life of Generator Belt; Size of Pulleys; Alinement of Pulleys; Lost Motion of Running Gears; Maintenance; Calculating Speed of Axle Generators 45–60

CHAPTER VII

PAGE

TRAIN LIGHTING STORAGE BATTERIES—I.—Lead-Lead Train Lighting Batteries; Types of Containing Vessels; Positive and Negative Groups of Plates; Method of Forming the Plates; Elements in the Lead-Lead Cell; Sediment, or Shedding of Active Material; Reason for the Growth of Plates; Ampere-Hour Capacity of a Lead Battery; Method of Maintaining the Capacity 61–78

CHAPTER VIII

TRAIN LIGHTING STORAGE BATTERIES—II.—The Edison Storage Battery—Containing Vessel, Groups of Plate, Positive Plates, Negative Plates, Electrolyte, Separators—Insulation, Trays, Chemical Action of an Edison Cell, a Complete Cycle in a Simple Form, Capacity and Charging Rates; The "Exide" Storage Battery—The Manchester Positive Plate, The Negative Plate, The Grids Assembled; The Putnam Storage Battery—Plate Construction, Assembly, Connections 79–96

CHAPTER IX

THE AMPERE-HOUR METER.—Storage Battery Efficiency; Types of Ampere-Hour Meters; Mercury-Motor Meter; Sangamo Ampere-Hour Meter; Overcharge Feature; Variable Resistor Element; Differential Shunt Feature; Manual Reset; Stop-Charge Feature; Increasing Light Load Accuracy and Compensation of Internal Battery Losses; Application of Sangamo Ampere-Hour Meters—with Axle Generator Equipment, with Straight Storage Equipment, with Head-End Equipment, Fundamental Principles of Application; Sangamo Circuit Breaker; Quick-Break Contact; Connecting a Sangamo Ampere-Hour Meter in a Circuit 97–112

CHAPTER X

MORE ABOUT THE AMPERE-HOUR METER.—The Theory of the Operation; The Direction of Armature Rotation; The Damping Disc; The Variable Resistor Element; The Theory of the Thermo-Couple; Testing Sangamo Ampere-Hour Meters; Graphic Ampere-Hour Meter for Car Lighting Service; Application of Graphic Meter 113–126

CHAPTER XI

LIGHTING CIRCUITS AND FIXTURES.—Car Lighting Fixtures; Day Coach Lighting; Pullman Car Lighting; The Fixtures in Dining Cars, Postal Cars, Private and Business Cars; Train Lighting Lamps; Classification of Bulbs; Meaning of "Lumen"; A Unit-Solid Angle; Electric Marker Lamps; Electric Fans for Passenger Cars; Switches and Cut-Outs: Snap Switch, Single-Pole Snap Switch, Double-Pole Snap Switch, Three-Way Snap Switch, Four-Way Switches, Electrolier Switches; Push Button Switches, Knife Switches, Plug Cut-Outs 127–139

CHAPTER XII

PAGE

INSTALLING A NEW CAR LIGHTING EQUIPMENT.—Material; Placing the Car on Trestles; Locating Battery Box and Cabinet; Installing Conduit; Wiring; Installing Panels; Under-Car Work 140–150

CHAPTER XIII

TESTING AND ADJUSTING CAR LIGHTING EQUIPMENT.—Battery Testing; Testing a Lead Storage Battery; The Cadmium Test Piece; Bringing Negative Plates Up to Capacity; Electrolyte; Correcting Specific Gravity; Testing a Nickel-Iron Battery; Testing Axle Generators and Regulators; Methods of Removing Generator from Car; Method of Testing 151–168

CHAPTER XIV

SERVICE INSPECTION AND TESTING.—Instruments Used in Testing Car Lighting Equipment; The Battery Voltage Readings; The Yard Electrician; Motoring Test; Ground Test; Armature and Main Generator Circuit; Inspecting an Armature Circuit; The Field Circuit Traced; Locating Trouble on a Car Lighting Equipment; Cell Voltage Reading; Testing for Grounds, Shorts and Open; To Locate a "Short"; A Method of Locating a "Ground"; To Locate an "Open"; Testing and Connecting a Three-Way and Four-Way Lighting Circuit . 169–180

CHAPTER XV

TOOLS FOR HANDLING CAR LIGHTING EQUIPMENT.—Tool for Removing and Applying Armature; Protecting Armature and Commutator; Press for Removing Armature Shaft and Bearings; To Remove a Bearing from the Shaft; To Remove Armature Shaft from the Armature; Applying and Removing Axle Generator Belt to Body-Hung Generator; Pulley and Bearing Puller; Pulley Driving Iron; Lining-up Axle with Body-Suspended Generator; Press for Lead Battery Plates; Wire Connectors for Car Lighting Batteries; Removing and Applying Battery Covers; Emergency Welding; Lifting Irons for Edison Batteries 181–190

CHAPTER XVI

E. S. B. CAR LIGHTING EQUIPMENT.—Generator; Generator Regulator; Body Suspension; Truck Suspension; Control Panel; Characteristics of the E. S. B. Equipment; Storage Battery . 191–214

CHAPTER XVII

THE GOULD "SIMPLEX" SYSTEM.—Generator; The Function of the Pole Changer; Generator Regulator; The Automatic Switch;

PAGE

The Field Rheostat or Carbon Pile; Generator Suspension; Operation; Operation of the Lamp Regulator; Adjustment of Generator Regulator; Adjusting the Automatic Switch; Adjusting Type M 2 Lamp Regulator; Earlier Types of Simplex Equipment 215–236

CHAPTER XVIII

Safety Car Lighting Equipment. — Generator; The Pole Changer; Generator Regulator; Lamp Regulator; Truck Suspension; Underframe Suspension; Operation; Operation of the Lamp Regulator; Safety F-1 Regulator; Safety FR Equipment; Suspension; Storage Battery; Adjustments; Generator Voltage Regulating Coil; Special Generator for Pullman Equipment; Special Type F for Pullman Company . . . 237–266

CHAPTER XIX

Stone-Franklin Car Lighting Equipment.—Generator; Automatic Panel; Operating Features; Operating with Sulphated Battery; Operating with Discharged Battery; Battery Control; Reducer Switch; Relay Switch; Lamp Voltage Regulation; Adjusting; Change-Over Switch; Belting; Operation . . . 267–280

CHAPTER XX

U. S. L. Car Lighting Equipment.—U. S. L. Type "A" Equipment; Generator; Regulator Panel; Operation of the Apparatus; Lamp Regulator; Voltage Coils; Ampere-Hour Meter; Generator Suspension; Belt Tension Device; Constant Belt Tension; U. S. L. Type C; Generator; Pole Changer; Generator Regulator; Adjusting Automatic Switch; Adjusting Generator Regulator When Not in Operation; Testing Type "B" Lamp Regulator; Testing and Adjusting Type "C" Regulator; U. S. L. Equipment—P. R. R. Specifications; Generator Regulator; Storage Battery; Operation 281–310

CHAPTER XXI

Direct-Drive Equipment for Axle Generators.—"Bliss" Drive; "Deutsch" Drive; "Fitz" Drive; "Gould" Shaft Drive; "Gould" Chain-Drive; "Matthews" Drive, "Matthews-Aves" Drive; "Pitt" Drive; "Safety" Direct-Drive; "U. S. L." Drive 311–320

APPENDIX

American Railway Association—Standards and Recommended Practices.—Specification for Axle Generators; Electric Train-Lighting, Standard Practice—General, Generator, Batteries, Wiring; Electric Train Lighting, Recommended Practice—General, Generator, Batteries, Wiring, Lamps, Axles . . . 321–352

Frontispiece.—Interior of Buffet Car. Showing Ceiling Lamps, Side Bracket Lamps, Desk Lamp, and Ventilating Fan.

CAR LIGHTING BY ELECTRICITY

CHAPTER I

THE HISTORY OF CAR LIGHTING

The illumination of passenger cars has been developed from a crude beginning, the first known attempt at car lighting being made in England in 1825. In that year the first passenger-carrying vehicle for railroad work—a coach called "Experiment" —was built for use on the Liverpool & Manchester Railroad. This car was drawn by a single horse and had seats along the side to accommodate six or eight passengers; a door and steps at the rear was the only means of entrance. It was leased to a Thomas Dixon, who operated it for several years between Stockton and Darlington.

The advent of the "Experiment" marked the beginning of car lighting; Thomas Dixon furnished a candle for illumination purposes on dark nights, the passengers being required to attend it themselves; later a table was placed in the center of the car to hold the candle. As the number of passenger cars increased, lighting methods improved, the first improvement being sockets placed on the sides of the car to hold the candles. Later chimneys were supplied to protect the flame; then a coiled spring was used in the bottom of the holder to force the candle up as it burned away, thus maintaining the flame at a predetermined position. This type of candle lamp is still in use as an auxiliary light in case of failure of the primary gas or electric system. The use of candles continued until the introduction of oil, about the year 1850.

The first oil lamps were a development of the improved candle lamps and gradually developed into the modern center draft

burners, which are still in use in certain parts of this country. Oil was superseded as an illuminant about 1875, at which time gas lighting was generally adopted. Coal gas was probably the first used, other kinds being used later. Gasoline mixed with air was very extensively used, as was also acetylene gas. Pintsch gas, invented in 1867, soon came into very general use on account of its reliability and the increased storage capacity obtained by carrying the gas under compression in tanks. The first gas lamps were of the flat-flame or fish-tail burner type. The mantle lamp was at first unsatisfactory, but suitable material was soon found, and this type of lamp was used extensively for car lighting purposes. At the present time both flat-flame and mantle lamps are still in use in some of the older types of passenger train equipment.

The first attempts at car lighting by electricity were made in 1881 and continued in an experimental stage for ten or fifteen years, during which time it reached a real and serviceable state. Three general methods have been developed, all of which are in use today; these three methods are:

Storage Battery System, in which the current is supplied exclusively by storage batteries, either as individual units on each car or one battery for lighting several cars.

Head-end System, in which current for the entire train is obtained by use of engine generating set.

Axle Generator System which provides lighting for each car as an individual unit.

The Straight Storage System, as the storage battery system is now termed, is the simplest method of car lighting but is not now considered flexible enough for general service. The first practical storage battery was developed in 1860 by Plante, in France; the pasted plate was a later development, being brought out by Faure, in 1878. The Plante type of battery was the first to successfully meet car lighting requirements.

In 1881, the London, Brighton & South Coast Railroad of England tried lighting some of their cars by means of a storage battery. Their experiment was not very successful and they soon developed a head-end system for the purpose, although also continuing the use of storage batteries alone. In 1886 a French road operated a train equipped with a set of bichromate primary

batteries, for about a year, between Paris and Brussels. This experiment was also very unsatisfactory, due to imperfect and expensive batteries, but with later developments of the battery, this type of equipment came into general use in France and other parts of Europe. In 1887 the Jura and Simplon Railroad in Switzerland began to install electric lighting by means of batteries and gradually installed this system on all of their cars. In Germany, the storage battery was very generally used, and, by 1893, twenty-five hundred mail cars alone were lighted by this method.

The use of storage batteries in America had its beginning about the same time as in Europe. In 1886 the Boston & Albany Railroad equipped a few cars with batteries but found it a rather costly experiment. In 1885 the Pennsylvania Railroad equipped eight parlor cars with batteries. This method was extended considerably by the Pennsylvania and today a majority of their cars are lighted only with storage batteries.

The Head-end System—so called because the entire train is lighted by means of a generator located at the front or head end—was the next development in car lighting. This was accomplished by several methods:

(1) Generator in the baggage car, driven by belt to car axle.

(2) Generator on the locomotive, driven by steam turbine.

(3) Generator in the baggage car, driven by steam turbine or gas engine.

In 1883 the London, Brighton & South Coast Railroad, England, mounted a generator in the guard's van and connected by a belt to the axle, using a storage battery auxiliary for light when the train stopped. A mechanical device served both as pole changer and automatic switch, the batteries being depended upon as a regulator. In 1884 the London & Northwestern Railroad employed a steam-driven dynamo on the back of the tender for lighting the entire train. No storage battery auxiliary was used. In 1887 the Pennsylvania equipped their Florida special trains with steam-driven generators in the baggage car. These original machines continued in operation until about 1902. In 1888 the Chicago, Milwaukee & St. Paul Railroad equipped a special car with a boiler and engine generator set to heat and light the entire train during the winter months. During the summer months this

engine and dynamo were transferred to the baggage car for lighting purposes. The Baltimore & Ohio Railroad also equipped several trains with this system at about this same time. In 1904 the Pennsylvania first used a steam-driven generator mounted on the engine for lighting trains, using batteries as an auxiliary. This system was later improved by the addition of the Gould booster, designed to boost the charging voltage to the batteries independent of the lamp circuit.

The Axle-generator System was developed about the same time as the head-end system, but was very unsatisfactory at first. It has been so much improved during recent years, however, that it has practically supplanted the turbo-generator equipment and is gradually pushing the straight storage system out of the field. The first axle-driven generator was of the head-end type but later individual units were applied to each car.

The axle generator system consists of a generator driven from the car axle, a set of batteries, and necessary regulating apparatus. A remarkably large number of these equipments were developed both in Europe and this country. About the first equipment of which there is any record was used on the Central Railroad of New Jersey in 1894. This was rather crude, but notwithstanding the large amount of mechanism involved, gave some satisfaction. About the first equipment in practical use was the Stone. This was invented in 1894 by A. B. Gill and improved and developed by J. Stone & Co., of Deptford, England, in 1896. This design uses a slipping belt for regulation and is the only one of its kind. Among the very numerous systems which were developed in Europe some of the best known and most used types of equipment were as follows:

The Vicarino and Dick equipments, perfected in 1900 and used principally in Austria and Turkey.

The Brown Boveri equipment, once used in England, but used very largely in Switzerland; perfected in 1902.

The Rosenberg equipment, using a generator having the property of supplying current in the same direction, irrespective of the direction of rotation. This type is used generally on the Prussian railroads.

The Pintsch Grob equipment used on Prussian and Saxon railroads, also on Austrian, Danish, Russian and Swiss railroads. It

was tried in this country but could not meet the requirements of American roads.

The Buttner equipment with Rosenberg generator, used exclusively in Germany.

The Electric Car Lighting Company's "GEZ" equipment with Rosenberg generator, used principally in Germany.

The Leitner equipment used in England.

The Mather-Platt equipment used in England.

Among the American equipments the earliest one was developed by Morris Moskowitz in 1895 and later improved by the U. S. L. & H. Co., which company also developed the Bliss equipments.

Another early equipment was one developed by the American Railway Electric Light Company. This was first put into service on a Pennsylvania car in 1896 and apparently was the first equipment to employ the principles of field rheostat control of generator voltage, a principle which forms the basis of many later equipments.

The McElroy equipment was developed by the Consolidated Car Heating Company about 1905.

The Safety equipment and the Gould & Newbold appeared between 1900 and 1910.

Later American equipments are the Stone-Franklin and the E.S.B. The Stone-Franklin equipment is practically the Stone system of Europe improved to meet American requirements. The E.S.B. system, perfected in 1913, makes use of the Rosenberg type of generator.

The practice of mounting generators has been radically different in Europe and America up until the last few years. Most of the European systems mount their generators on the body of the car while until very recent years the practice in this country has been to mount the generator on the truck. Some of the early American generators were mounted on the body of the car but they soon discarded this method in favor of the truck suspension. In the last few years, however, the use of body-suspended generators has been generally adopted in this country. The Safety equipment was the first of the modern equipments to be suspended from the body of the car, a special device being used for constant belt tension. Other equipments are now also body-suspended.

With the generators hung on the truck of the car various kinds

of drives were tried, but the present rubber belting has generally been adopted. Some of the methods used were: chain belts operated over cog wheels, instead of pulleys; V-shaped leather belting operating in V-faced pulleys; and the generator geared to the car axles, on the same principle of the trolley car motor. Another method tried was the mounting of the armature on the car axle and the fields on the truck of the car. A body suspended generator was also developed which was driven by a shaft, connected with the axle by cogs. These methods proved unsatisfactory and expensive and were discontinued.

One of the old drawbacks of car lighting was the heavy current consumption of the old carbon lamp, but with the improvements in the incandescent lamp economical car lighting became possible, as the demand on the batteries for current was brought within the necessary limits for battery capacity and weight possible to be carried on a car. Incandescent lamps were used before but did not come into general use for car lighting service until about 1900, and have gradually developed to their present state of efficiency.

Another great improvement in car lighting equipment was the perfection of ball bearings for generators. These were first used about 1912 and have been generally adopted since, practically revolutionizing car lighting by cutting down maintenance cost.

CHAPTER II

THE STRAIGHT STORAGE SYSTEM

The straight storage system of car lighting is a system in which the current for lighting the car is supplied exclusively by storage batteries, either as individual units on each car or one battery for lighting several cars. The battery for a 30-volt system contains 25 Edison cells or 16 lead cells, while the battery for a 60-volt system contains 50 Edison cells or 32 lead cells. Generally the

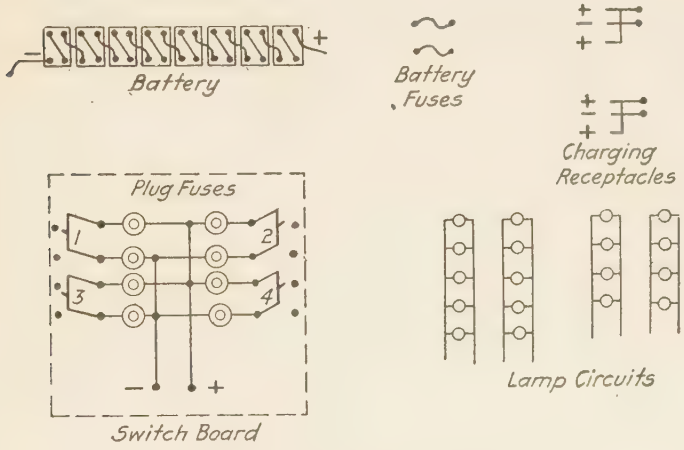


Fig. 1—Parts of a Simple Straight Storage System.

battery is carried in specially designed boxes which are suspended from the car body.

Battery fuses are mounted on each side of the car in iron boxes which are constructed for the purpose. Two wires carry the current from the battery and battery fuses to a switchboard or distribution panel which is located inside the car. Upon reaching this switchboard the current is distributed through protecting fuses and control switches to the various lamp circuits. Charging

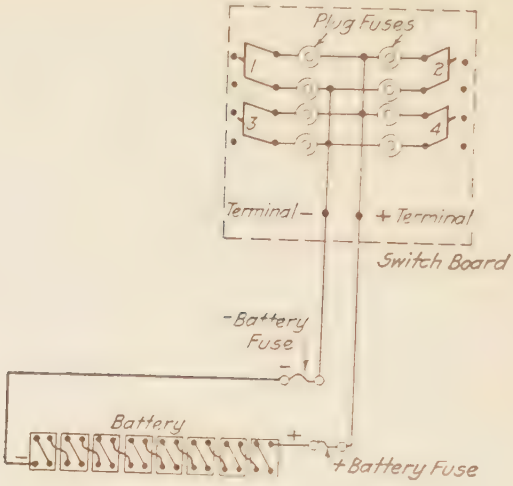


FIG. 2—Battery and Panel Board Connected.

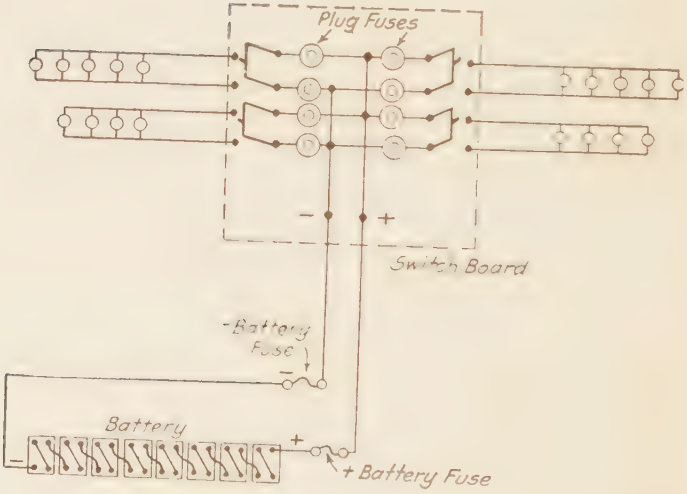


FIG. 3—Battery, Panel Board and Lamp Circuits Connected.

receptacles of 125-volt, 100-ampere capacity are mounted on each side of the car to provide connections for charging the battery at the railroad terminals.

To study this system more fully construct a simple straight storage system, by taking the various parts as shown in Fig. 1 and connecting them step by step.

First run two service wire or battery wires from the battery to the battery fuses, then to the switchboard, as shown in Fig. 2.

Second, connect the two wires from each lamp circuit to the switchboard, as shown in Fig. 3.

Third, connect the two charging receptacles to the main battery

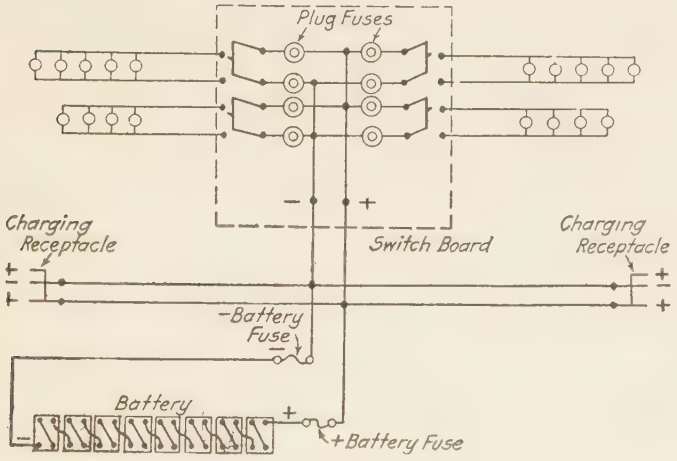


Fig. 4—Parts of a Simple Straight Storage System Connected.

wires, as shown in Fig. 4, which is a complete wiring diagram of a simple straight storage system. Two charging-receptables are connected so that the battery may be charged from either side of the car.

A complete straight storage system having been constructed, it will be interesting to study the path of the charging and discharging currents.

Fig. 5 shows a straight storage system with the lights burning, that is, with the lighting switches all closed. The arrows point in the direction of the flow of current. Starting at the + battery terminal the current flows through the + battery fuse to the +

terminal of the switchboard whence it branches off in four directions, sending one wire to each lamp circuit. Passing through the lamps the current returns through four wires, one from each lamp circuit to the — terminal of the switchboard whence it returns through the — battery fuse to the — battery terminal.

The charging current can be traced by following the arrows in Fig. 6. The current from the yard charging plant enters through the + side of the charging receptacle, flows through the + battery fuse to + battery terminal, through the battery to the — battery terminal, returning to the charging plant through the — battery

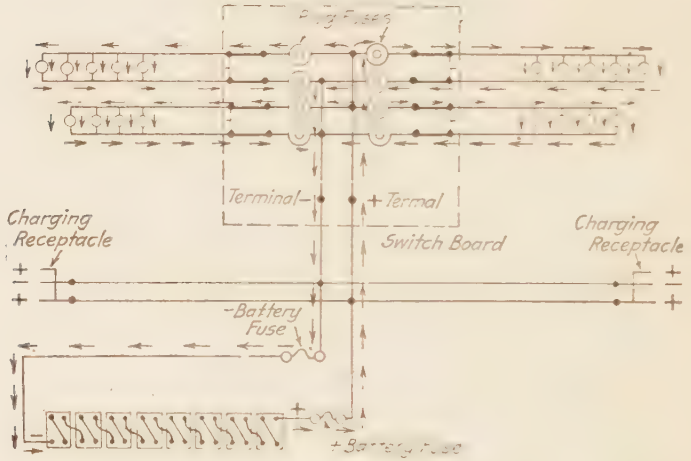


FIG. 5—Straight Storage System With Lighting Switches Closed and Arrows Indicating Direction of Current Flow.

fuse and the — side of the charging receptacle. By comparing Figs. 5 and 6 it will be seen that the charging current flows through the battery in the opposite direction to the flow of the discharging current. The lights should *not* be on while the battery is charging as the voltage on the lighting circuits is increased while the battery is on charge.

Some straight storage systems are equipped with Sangamo ampere-hour meters and stop charge, shunt-trip circuit breakers. The meter and circuit breaker are both mounted on a slate panel which is known as the Sangamo control panel.

The function of the control panel is to give an indication of the

battery charge and discharge and to limit the charge by automatically opening the stop-charge circuit breaker.

Fig. 7 is a wiring diagram of a straight storage system equipped with a Sangamo control panel. By tracing the flow of current in Fig. 7 as was done in Figs. 5 and 6 it will be seen that the charging current passes through the Sangamo meter in one direction and the discharging current in the opposite direction. This change of direction of current moves the hand on the meter dial accordingly and when the battery is fully charged the hand on the meter dial will close switch *A*, Fig. 7, which in turn opens circuit breaker *Y*

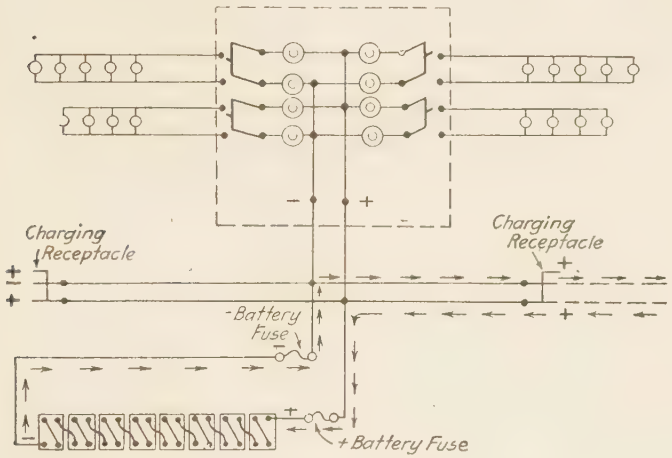


FIG. 6—Battery on Charge, Showing Lighting Switches Open.

and stops the charge. A full description of the Sangamo meters used in car lighting is given in detail in a following chapter.

Increasing Battery Storage Capacity for Special Cars.—In some special cases it is desired to increase the storage capacity of the battery by using more than one set of batteries and connecting them in different ways for charging and discharging by using standard voltage lamps and the standard charging equipment.

For example, Fig. 4 is a diagram of a 30-volt straight storage system with one 30-volt set of batteries. If each cell had a capacity of 300 ampere hours, the total capacity of the battery at 30 volts would be 300 ampere hours. If the lamp consumption was 600 watts, the lamp current would be 600 ÷ 30, or 20

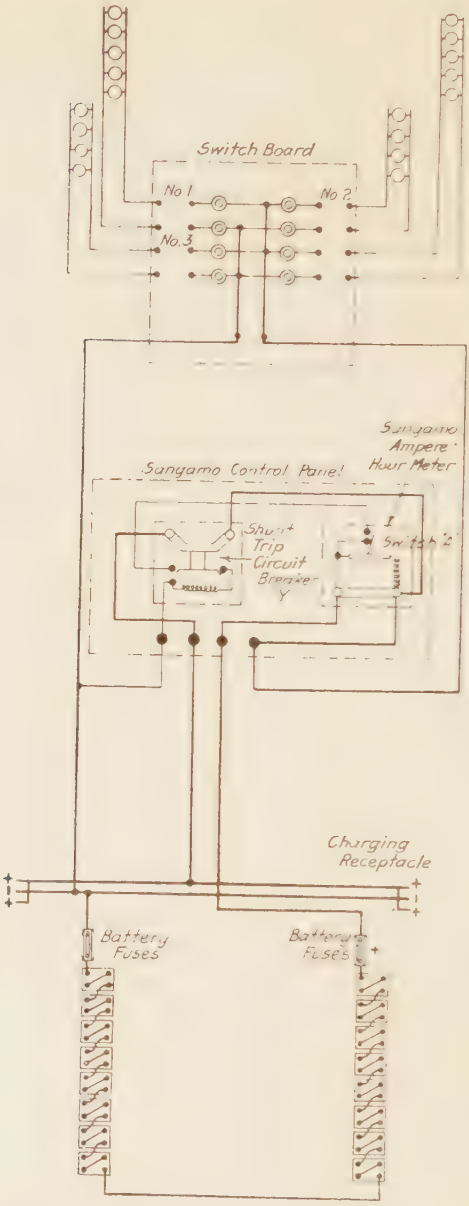


FIG. 7—Straight Storage System Equipped With Sangamo Control Panel.

amperes, and with a lamp current of 20 amperes the battery will light the car for 300 ÷ 20, or 15 hours.

To increase the storage capacity of this car a choice of two schemes may be used; use two sets of batteries in series and

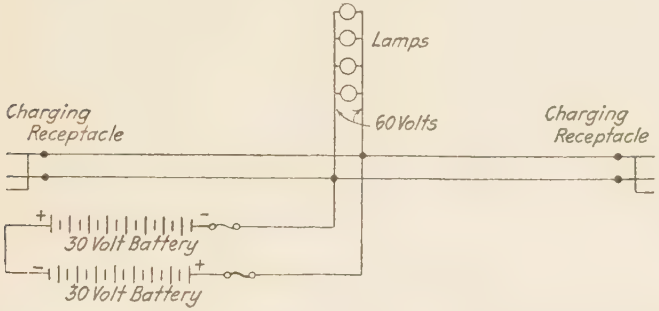


FIG. 8—A 60-Volt Straight Storage System—Two 30-Volt Sets in Series.

change the lamps in the car to the standard 60-volt lamps; or connect two 30-volt sets of batteries in multiple using the standard 30-volt lamps.

Fig. 8 shows two 30-volt sets of batteries in series. The ampere

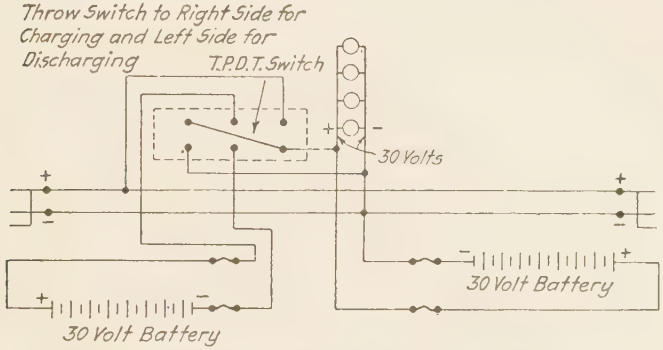

Throw Switch to Right Side for Charging and Left Side for Discharging
T.P.D.T. Switch
30 Volts
30 Volt Battery
30 Volt Battery

FIG. 9—A 30-Volt Straight Storage System Having Two Sets of Batteries Connected in Multiple on Discharge and in Series on Charge.

hour capacity of the battery using 300 ampere hour cells will be same as above, 300 ampere hours, but the voltage on the lamps is increased to 60 volts. With a lamp consumption of 600 watts the lamp current will be 600 ÷ 60, or 10 amperes. And with a lamp

current of 10 amperes the battery will light the car for 300 ÷ 10, or 30 hours. This is just double the time that one set of batteries will light the car.

Fig. 9 shows two 30 volt sets of batteries connected in multiple on discharge and in series on charge. The charging in series is preferred because the two sets will charge more evenly in series than in multiple.

The ampere hour capacity of the battery in this case using the 300 ampere hour cells will be 300 times 2, or 600 ampere hours. With a lamp consumption of 600 watts at 30 volts the lamp cur-

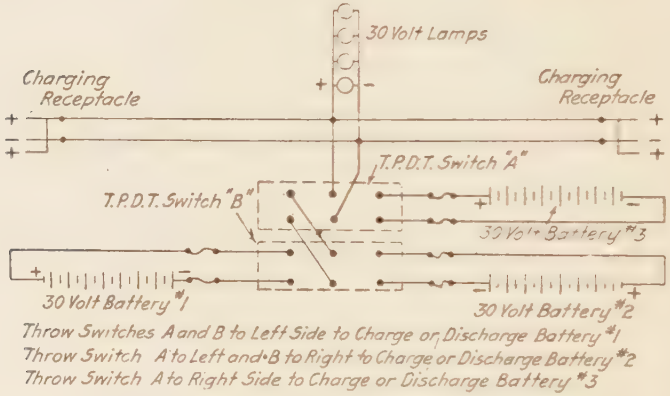

30 Volt Lamps
Charging Receptacle
Charging Receptacle
T.P.D.T. Switch "A"
T.P.D.T. Switch "B"
30 Volt Battery #3
30 Volt Battery #1
30 Volt Battery #2
Throw Switches A and B to Left Side to Charge or Discharge Battery #1
Throw Switch A to Left and B to Right to Charge or Discharge Battery #2
Throw Switch A to Right Side to Charge or Discharge Battery #3

FIG. 10—A 30-Volt Straight Storage System Having Three Sets of Batteries—One Set in Service and Two Sets in Reserve.

rent will be the same as in Fig. 4, which is 600 ÷ 30, or 20 amperes, and the battery will light the car for 600 ÷ 20, or 30 hours, the same length of time as in Fig. 8, where there are two 30-volt sets of batteries in series.

To make the storage capacity still greater three 30-volt sets of batteries may be used as follows:

Fig. 10 shows three 30-volt sets of batteries connected to two 2-pole double-throw switches. Throwing switches *A* and *B* to the left side charges or discharges battery No. 1 and batteries No. 2 and No. 3 are held in reserve. Throwing switch *A* to the left and switch B to the right side, charges or discharges battery No. 2 and batteries No. 1 and No. 3 are in reserve. Throw switch *A* to the right side to charge or discharge battery No. 3 and hold

batteries No. 1 and No. 2 in reserve. The ampere hour capacity of the battery in this case using 300 ampere hour cells will be 300 times 3, or 900 ampere hours. With a lamp consumption of 600 watts at 30 volts the lamp current will be 600 ÷ 30, or 20 amperes; and the three sets will light the car for 900 ÷ 20, or 45 hours, just three times as long as in Fig. 4 where only one set of batteries is used.

Lighting from One Set While the Other Set Charges.—It has already been stated that the lights should be off while the battery on a straight storage system is charging, because of the

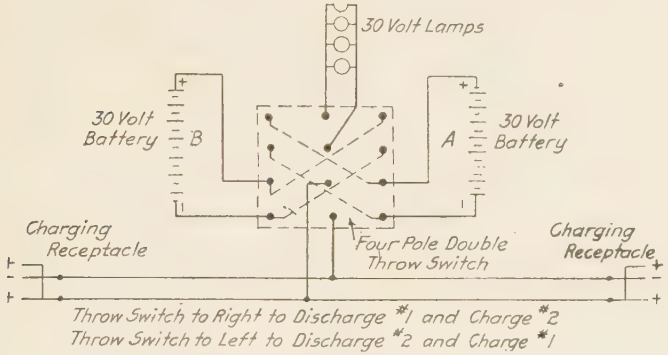

30 Volt Lamps
30 Volt Battery B
A 30 Volt Battery
Charging Receptacle
Four Pole Double Throw Switch
Charging Receptacle
Throw Switch to Right to Discharge #1 and Charge #2
Throw Switch to Left to Discharge #2 and Charge #1

FIG. 11—A 30-Volt Straight Storage System With Two Sets of Batteries.

increased lamp voltage; it will be noted that in Figs. 4, 8, 9 and 10 there is no way to get light on the car while the battery is charging without placing the increased voltage on the lamps. A scheme for overcoming this by using two sets of batteries is shown in Fig. 11. Either set of batteries may be charged while the other is furnishing current to light the car. Throwing the 4-pole double throw switch to the right side charges battery *A* and discharges battery *B*; to the opposite or left side charges battery *B* and discharges battery *A*. These schemes are in use in special cases on various railroads.

Advantages and Disadvantages of the Straight Storage System.—The straight storage system has some advantage over the other methods of car lighting by electricity in that it is very simple, not having any complicated mechanism. It is also reliable,

having a positive source of current as long as the battery charge lasts.

It has one great disadvantage, however, in that it requires that the cars be taken out of service and placed in the terminal yards from six to eight hours for recharging batteries. This system also requires an expensive charging plant at each terminal, the wiring of which must be designed so that cars can be charged while on any track in the car yard and the generator must be large enough to charge the maximum number of cars at one time.

CHAPTER III

HEAD-END SYSTEM

The "head-end" system of car lighting has a generator located at the head end of the train to furnish power for lighting the entire train. This system had its beginning about 1887 and was later developed into several different methods or designs:

1. Generator in baggage car driven by belt to car axle.
2. Generator on locomotive driven by steam turbine.
3. Generator in baggage car driven by steam turbine or gas engine.

The Train Line.—Fig. 12 is a diagram of a four-car train with the lighting circuit of each car connected to the generator. It will be noted that only two wires are shown from the generator to the

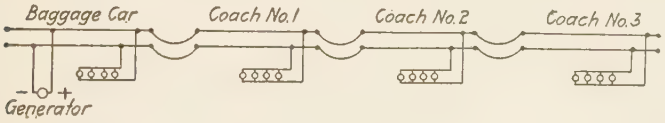


FIG. 12—Generator in Baggage Car and Driven By Steam Turbine.

extreme end of the train. While two wires would complete the circuit, it is not a practical arrangement and is given here as a matter of simplicity for illustrating. If only two wires were used in the train line with no other apparatus, as shown in Fig. 12, the lamps in the various cars would not burn with a uniform brilliancy —the car nearest the generator would have the brightest light. For example, if there was a sufficient lamp load to give a five-volt drop in the train line of each car, with a voltage of 65 at the generator, coach No. 1 would receive 60 volts, coach No. 2 would receive five volts less or 55 volts, coach No. 3 would receive five volts less than coach No. 2 or 50 volts. To overcome this unbalanced condition, the three-wire train line is used. The three wires are connected so that the lighting current for each car travels through

the same length of wire. If the circuit to each car contains an equal amount of wire the voltage drop to each car will be the same, resulting in the lamps in all cars throughout the train burning with equal brilliancy. This is illustrated in Fig. 13, which shows a diagram of a four-car train with a three-wire train line. Wire No. 1 runs from the generator to the rear of the train, where it is connected by a loop to wire No. 2. Wire No. 2 feeds the positive side of the light circuit on each car. Wire No. 3 connects the negative side of each light circuit with the negative side of the generator. By using the distances between points, as given in Fig. 13 the number of feet of wire the current travels through for

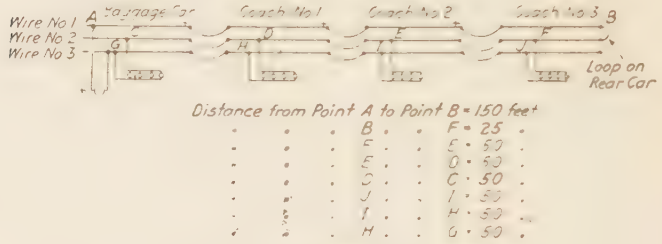


Fig. 13—Three-Wire Train Line.

lighting each car can be calculated and it can be shown that it is equal for each car. Starting at the positive side of the generator, the current for lighting the baggage car will travel from point *A* to point *B*, then to point *C*, a distance of 150 plus 175 or 325 feet. The negative side of the light circuit of the baggage car and the negative side of the generator are one, so that the total amount of train line wire which the current for lighting the baggage car travels through is 325 feet. The current for lighting coach No. 1 travels from point *A* to point *B*, to point *D*, returning from point *H* to point *G*, a distance of 150, plus 125 plus 50 or 325 feet. The current for lighting coach No. 2 travels from point *A* to point *B*, to point *E*, returning from point *I* to point *G*, a distance of 150 plus 75 plus 100 or 325 feet. Current for coach No. 3 travels from point *A*, to point *B*, to point *F*, returning from point *J* to point *G*, a distance of 150 plus 25 plus 150 or 325 feet. This proves that the current for lighting each car travels through 325 feet of train line wire. Therefore the voltage drop to each

car will be equal and the lamps throughout the train will burn with equal brilliancy.

Method of Connecting Train Line Wires.—While on the subject of a three-wire train line, it will be pertinent to describe the method of connecting the train line between cars. The Gibbs train line connector is in common use. The female portion of this connector is fixed to each end of the car and connected to the ends of the train line wires, Fig. 14. The train line on one car is con-

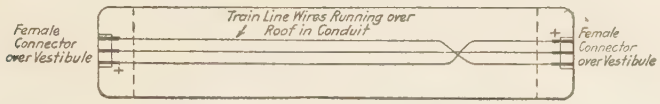


FIG. 14—Female Gibbs Connector at Each End of Car.

nected to the train line on the adjoining car by a train line jumper. This jumper consists of two male plugs connected together with three flexible cables, as shown in Fig. 15. The two outside train line wires are crossed on each car as a means of making the connections of the female connectors at each end of the car uniform. The uniform rule is to place the positive terminal to the right, facing the end of the car. This uniformity of connectors makes it possible to connect the train lines of the various cars

FIG. 15—Train Line Connectors Used Between Cars.

throughout the train by using a standard train line jumper, and the cars may be placed in the train without regard to which ends of cars adjoin. To explain this more fully, suppose that the train line wires on each car were not crossed, but instead, connected straight through, as shown in Fig. 16. Then facing the *A* end of each car, the positive wire would be connected to the left-hand terminal of the female connector and facing the *B* end of each car, the positive wire would be connected to the right-hand terminal of the female connector. This would work out successfully if the *A* end of one car were connected to the *B* end of the adjoining car. But if, by

chance, the cars were turned so that the two *A* ends adjoined, the wires would be crossed when the jumper was connected. To overcome this, the two outside wires are crossed on each car, as shown in Fig. 18, and when either end of one car is connected to either end of the other car, the connections are standard throughout.

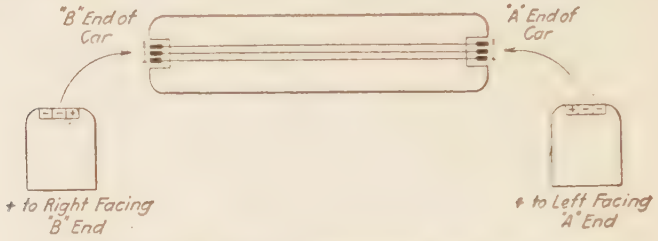


Fig. 16—Wrong Way of Connecting Train Line Wires.

The male Gibbs connector is designed so that it can be inserted in the female portion in but one way, as shown in Fig. 17. The train line jumper is connected straight through as shown in Fig. 15, but when it is inserted between cars it is twisted so that the two outside wires are crossed again and the right side or positive

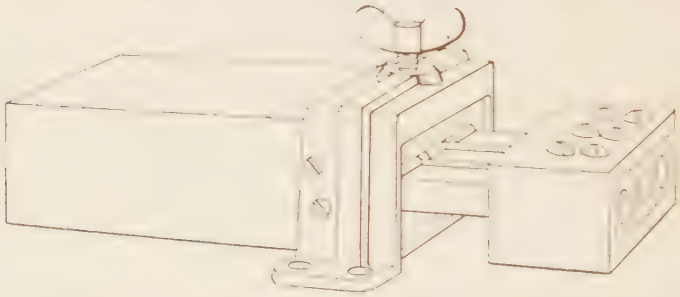


Fig. 17—Plug Can Be Inserted in Receptacle in Only One Way Due to Arrangement of Insulation Between Fingers.

side of the female connector of one car is connected to the right side or positive side of the female connector of the adjoining car, that is, the right side of each female connector facing the end of each car respectively, as in Fig. 18. Each female Gibbs connector is equipped with a loop or shunt which is operated either by hand or automatically. The function of this loop is to connect two of the three train line wires together, when it is desired, at various points in the train. The improved Gibbs train line connector is

constructed so that the loop is made automatically when the plug is removed from the receptacle, and is opened when the plug is inserted. This automatic attachment also holds the plugs in place and locks the automatic loop. The automatic loop female Gibbs connector is taking the place of the old hand loop type, as it provides a loop at the rear of the train, where a loop is needed at all times. Should a connector between the rear car and the dynamo car become disconnected from any cause, then the improved automatic loop completes the circuit and prevents the lights going out on the entire train. The Gibbs train line connectors are designed for the following ampere capacity—

No. 1 G 100 to 150 amperes 250 volts
No. 2 G 175 to 200 amperes 250 volts
No. 3 G 225 to 250 amperes 250 volts

Arrangement of Head-end Systems.—A head-end system with a generator only for supplying the current to light the cars in the

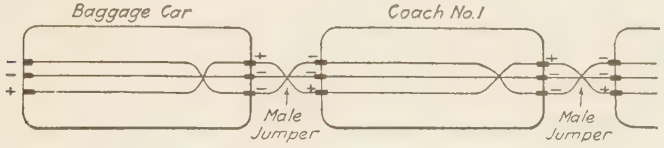


FIG. 18—Proper Method of Connecting Train Line Wires.

train is known as the straight head-end system. With this system, when a train is disconnected for the purpose of cutting off cars, the cars back of the disconnecting point in the train are thrown in darkness or, if anything happens to the generator, the whole train is thrown in darkness until the generator is repaired. Also, when the engine is not attached to the train to furnish the steam to drive the turbine, the train is in darkness.

To overcome this trouble it was found necessary to place storage batteries on the first and last cars of each train so that, if the generator failed, the batteries would furnish current to light the train, or if the train was parted to cut in or cut out cars, each section would have light. This system was a failure on trains with heavy loads, because of insufficient battery capacity. Consequently, storage batteries were applied to each car, which greatly increased the time that lights could be depended upon in case of the generator being out of service, and also made it possible for each car to have light when cut off individually. The addition of

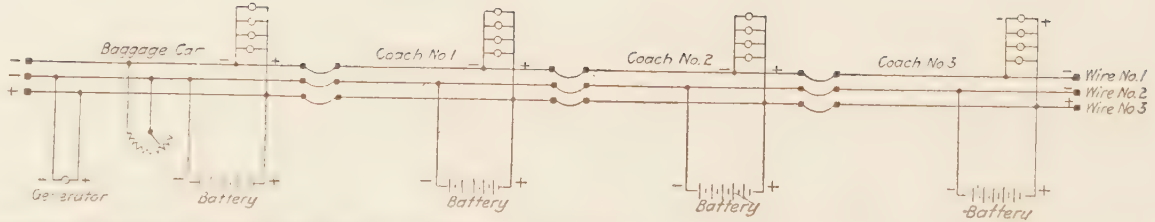


FIG. 19—Batteries Charged Across Full Generator Voltage. Resistance Cut-in Light Circuit to Give Proper Voltage at Lamps.

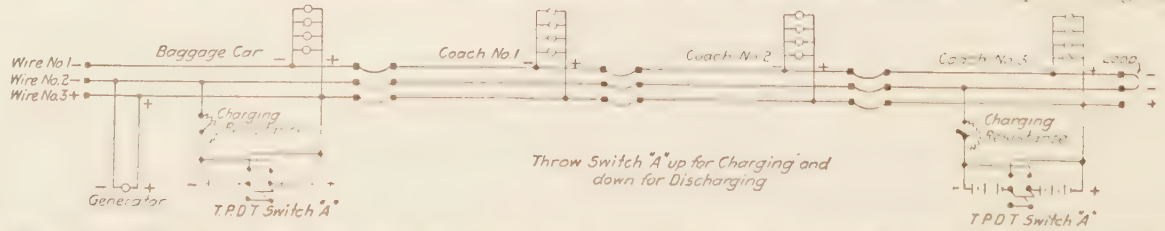


FIG. 20—For Charging, the Battery Is Split Into Two 30-Volt Sets, Which Are Charged in Parallel in Series with an Adjustable Resistance. The Generator Voltage Is Kept So That the Lamps Receive Their Rated Voltage.

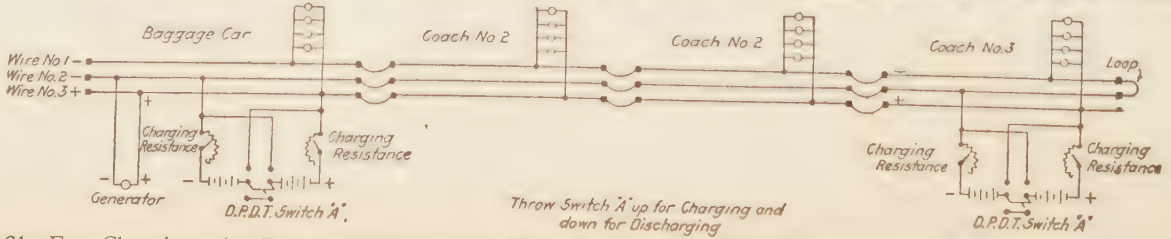
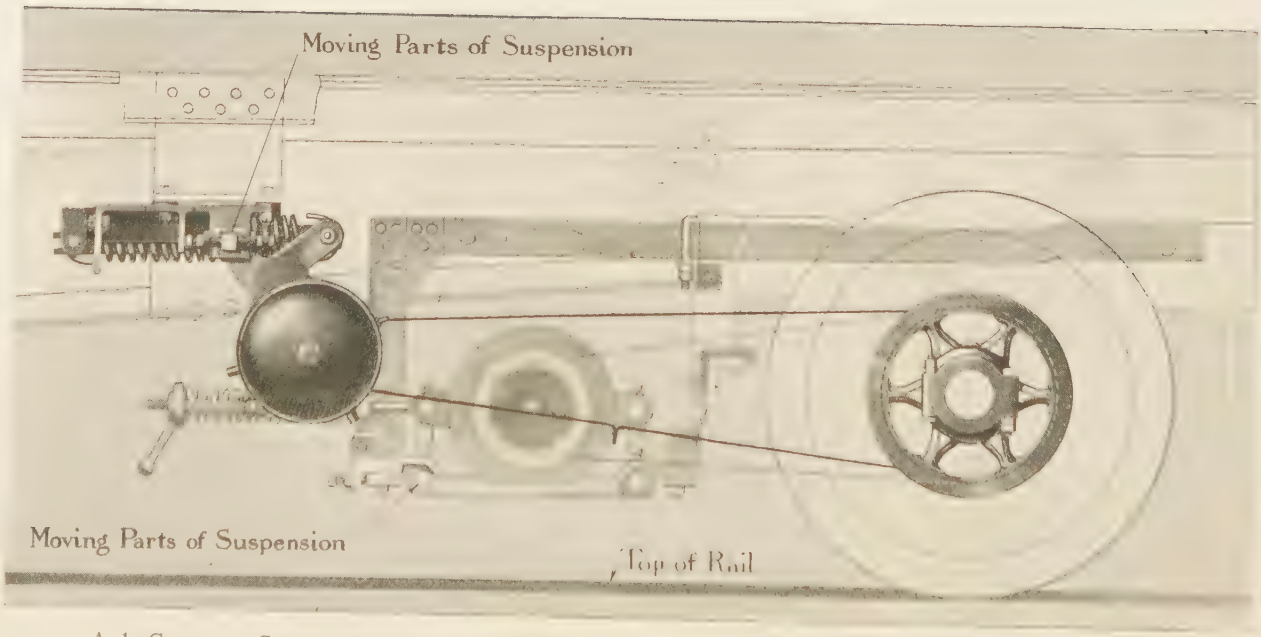


FIG. 21—For Charging, the Battery Is Split Into Two 30-Volt Sets, Which Are Charged in Parallel, with an Adjustable Resistance in Series with Each 30-Volt Set.

batteries to the head-end system added another problem to solve and that was the charging of the batteries, particularly while the lights were burning. A much higher voltage is required to charge a storage battery than the battery will give on discharge. Therefore, it was necessary to make some provision for protecting the lamps while the battery was charging. In dealing with this problem, many roads developed a system to meet the conditions as they existed on its particular lines, which resulted in several different schemes of wiring, battery charging and operation. Today, however, the standard three-wire system of wiring and standard connectors are used in making connections between cars and the wiring systems as a whole differ only in the method of charging batteries.

On the C. B. & Q., C. M. & St. P., Great Northern, and Northern Pacific roads each set of batteries is charged with its cells connected in series across the full generator voltage, and the resistance is cut in series with the lighting circuit to give proper voltage at the lamps, as in Fig. 19.

On the C. & N. W. and old Harriman lines the generator voltage is kept so that the lamps receive their rated voltage and the battery on each car when charged is split into two 30-volt sets which are charged in parallel, in series with a suitable resistance. This changing of battery connections for charging is accomplished by means of a double-throw switch in each car, as shown in Fig. 20 and Fig. 21.



Axle-Generator System—Body-Suspension Type Shown in Relief, Truck-Suspension Type in Phantom.

CHAPTER IV

AXLE-GENERATOR SYSTEM

The system of car lighting employing axle driven generators was developed about the same time as the head-end system, but at first was very unsatisfactory in operation. It has been so much improved during recent years, however, that it has practically supplanted the turbo-generator equipment and is gradually pushing the straight storage system out of the field.

The axle generator system consits of a generator driven from the car axle; a set of storage batteries; and necessary regulating apparatus. When the car is in motion, the generator is automatically connected to the battery and lighting circuits, after which it furnishes current to charge the storage battery, and also to light the car. When the car is at rest, the generator is automatically disconnected from the battery and lighting circuits and the storage battery supplies the current for the lamps. This equipment is applied to each car, therefore it is an individual unit and the car may be placed in any line of service without it being necessary to adjust any of the apparatus.

There are two methods of suspending axle generators in general use: the body type—generator suspended from the car body; the truck type generator suspended from the truck of the car.

The axle generator is driven by a belt or chain from the car axle by the use of two pulleys, one, a large pulley, being bolted on the car axle and known as the axle pulley. The other, a much smaller pulley, is mounted on one end of the armature shaft and is known as the generator pulley.

Car Lighting Generators.—All generators used in the axle generator system of car lighting are direct current machines because direct current is required to charge a storage battery. These generators must also be water and dust proof, as they are suspended under the car and are operated in all kinds of weather.

Because of this operating condition the circulation of air around the outside of the machine is depended upon to assist in keeping the generator at a safe operating temperature.

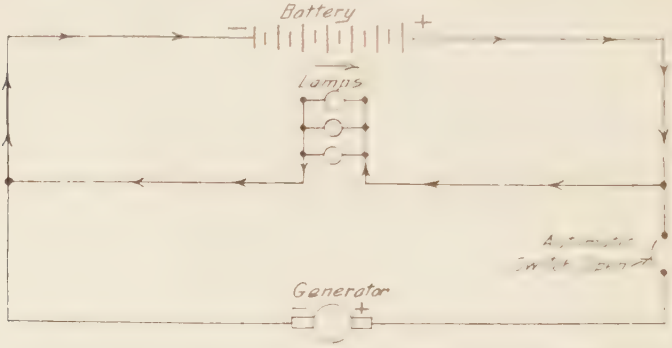


FIG. 22—Car Not in Motion, Automatic Switch Open, Lights Burning—The Current Flows From the Battery as Shown by Arrows.

The speed and direction of rotation of the armature of an axle generator depends upon the speed and direction that the car is traveling, and, as the car operates in either direction and at all rates of speed, perfect commutation is necessary over a wide range

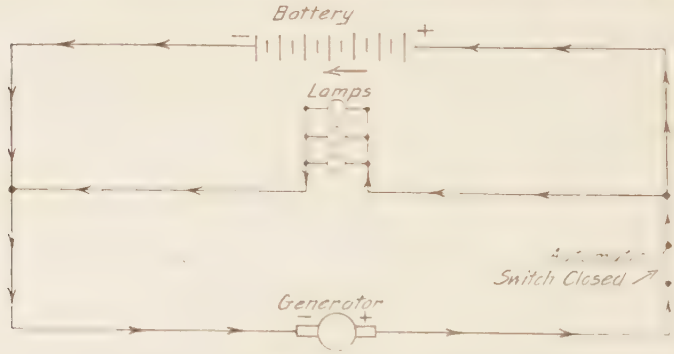


FIG. 23—Car in Motion, Automatic Switch Closed, Lights Burning—The Current Flows From the Generator to Battery and Lamps as Indicated by Arrows. The Charging Current Passes Through Battery in Opposite Direction to That of Discharge Current as Shown in Fig. 22.

of speed in either direction. This is accomplished by setting the brushes for a full load for the average train speed, which gives good commutation at speeds below or above the average.

The change in direction of rotation of the armature as the car is

operated in either direction, gives rise to another problem—the question of polarity. When a storage battery discharges, the current will flow from the positive terminal of the battery to the lamps and return to the negative terminal of the battery, as shown in Fig. 22. When charging a battery it is important that the charging current shall flow through the battery in the opposite direction to that of the discharging current—shown in Fig. 23. Therefore when a set of batteries is connected to an axle generator the positive side of the generator must be connected to the positive side of the battery, and the negative side of the generator connected to the negative side of the battery.

The correct polarity to be used in charging a battery being known, the question arises as to the polarity of the generator when

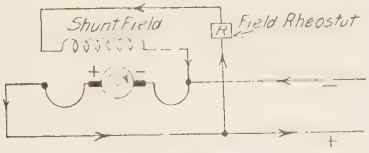


Fig. 24.

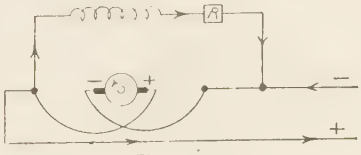


Fig. 26.

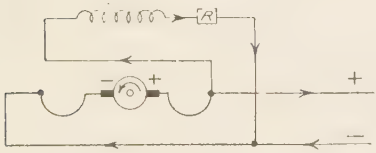


Fig. 25.

Figs. 24, 25, and 26—Showing the Direction of Current Flow in the External Circuit With Relation to the Direction of Armature Rotation.

the direction of the armature rotation changes. It is not intended here to enter into a discussion of elementary electricity; it might be well to include briefly the relation between the direction of rotation of the armature to the polarity of a shunt wound direct current generator before describing the operation of the pole changers used in direct current shunt wound axle generators.

Direction of Rotation.—If, when facing the commutator end of the armature of a dynamo, the rotation is in the direction of the hands of the clock, it is said to be *clockwise,* while the reverse direction is called *counter-clockwise.* If it is desired to reverse the direction of rotation of the same dynamo the connections between field and armature must be changed so that the current will flow through the field as before, otherwise the machine will not

pick up. Fig. 24 shows the connection of a shunt wound machine for a clockwise rotation; Fig. 25 shows the same machine arranged for counter-clockwise rotation with reverse polarity of the line wires; and Fig. 26 shows the connections for the counter-clockwise rotation retaining the same polarity of line wires as in Fig. 24. In both Figs. 24 and 25 the direction of the current through the field remains unchanged so that there is no disagreement between the direction of the field magnetism and that of the residual magnetism.

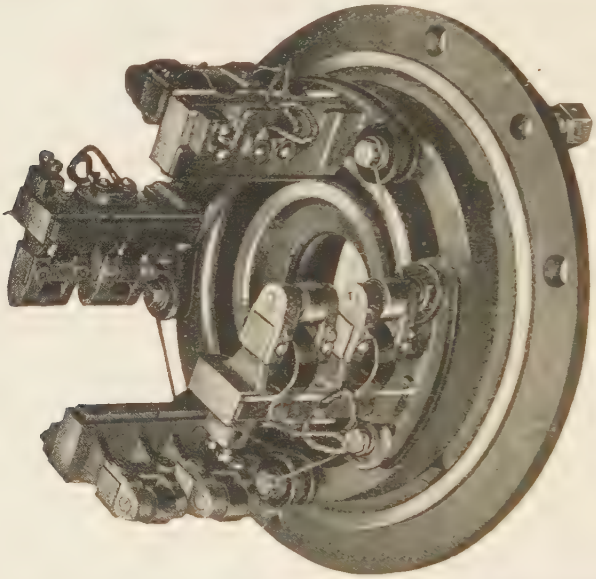


Fig. 27—Rotating Type of Pole Changer Mounted on Housing Head.

Shunt-wound axle generators are equipped with a pole changer which keeps the polarity of the external generator leads constant regardless of the direction of armature rotation.

The parts of a shunt-wound direct-current generator used for car lighting are the magnet frame, housing heads, poles, field coils and retainers, armature, brushes and brush holders, and pole changer.

Magnet Frame. The magnet frame is a one piece casting which houses the armature, field coils, and pole pieces, and also carries the housing heads. The magnet frame is provided with

hand holes at the commutator end for inspection purposes. These holes have water and dust proof covers.

Housing Heads.—The housing heads carry the ball bearings and are bolted to the magnet frame at each end.

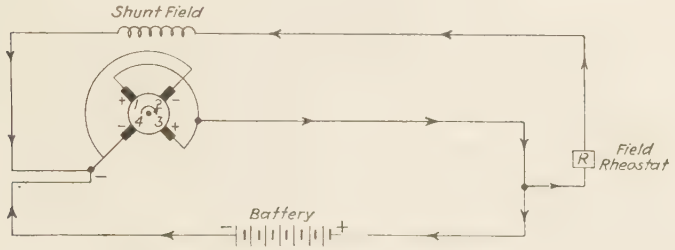


FIG. 28—Armature Rotating in Clockwise Direction. Battery Receiving Current With Correct Polarity.

Poles.—The poles are of the laminated type bolted to the magnet frame.

Field Coils and Retainers.—The field coils are held in position by the pole pieces and by field coil retainers which are either made of brass and bolted to the magnet frame or of wood and wedged

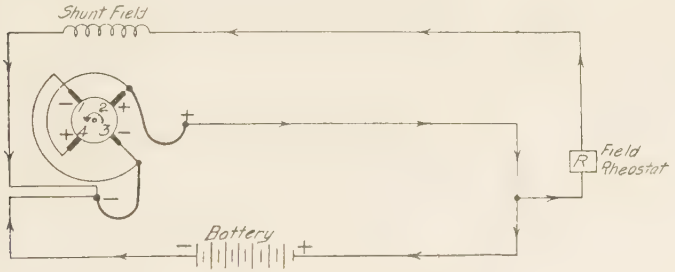


FIG. 29—Armature Rotating in Counter-Clockwise Direction. Position of Brushes Has Shifted but Direction of Current in External Circuits Is the Same as in Fig. 28.

between the pole pieces. The retainers make it impossible for the field coils to slip or wear by rubbing against the pole pieces.

Armature.—The armature is form wound. The coils are held in the core slots by hard fiber or wooden wedges and band wires. The armature core is built up of transformer iron laminations. Air spaces are provided in the core to secure cool running. The

commutator bars are of hard drawn copper and insulated by a good grade of mica.

Brushes and Brush Holders.—The brushes are of carbon which will not cut or gum the commutator. They are provided with flexible copper pigtails to give positive contact with the brush boxes. Each brush is provided with a separate spring of such design that the pressure on the brush is constant until the brush reaches its limit of wear. The brush boxes are brass or aluminum cast and are four in number.

Pole Changer.—There are two types of pole changers in general use today—the *rotating* type and the *mechanically operated switch* type.

The rotating type pole changer, Fig. 27, rotates the generator brushes through an angle of 90 degrees whenever the direction of armature rotation is changed. The four brush boxes are mounted on, but insulated from, a brush rocker which forms the outer race of a ball bearing and which is free to move through an arc of approximately 90 degrees. The friction between the brushes and the commutator is easily sufficient to rotate the pole changer or brush rocker when the direction of armature rotation changes and the length of the arc of travel is determined by suitable stops on the pole changer rocker and on the housing head, these stops being so located that for either direction of car movement the brushes are placed in the proper position to secure good commutation. The principle involved in this type of pole changer is as follows:

Starting with a car operating so that the armature rotates clockwise and the field and generator current flowing in a direction as shown by arrows in Fig. 28, the battery is receiving the charging current with the correct polarity. Before reversing the direction of rotation, note that the two positive brushes are placed at points 1 and 3 on the commutator and the two negative brushes at points 2 and 4.

Next assume that the same car is operated in the opposite direction as shown in Fig. 29. The moment that the armature reverses its direction of rotation, the friction of the brushes on the commutator carries the brushes through an arc of 90 degrees against a stop, placing the positive brushes at points 2 and 4, instead of 1 and 3, on the commutator and placing the negative brushes as shown at points 1 and 3 instead of 2 and 4. The field current and

the generator current to the battery flow in the same direction as in Fig. 28, which shows the armature rotating in the opposite direction.

The mechanically operated switch type pole changer, shown in

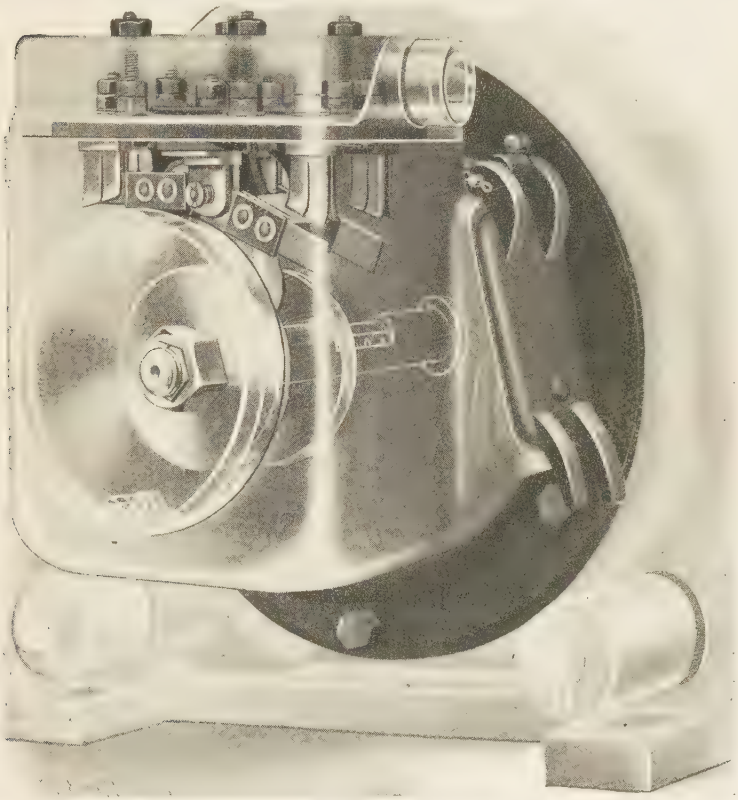


FIG. 30—Phantom View of Pole Changer with Armature Rotating in Clockwise Direction, Trip About to Throw Pole Changer Switch so as to Reverse Connections.

Figs. 30 and 30a, consists of a double-pole double-throw knife switch connected between the brush leads and the external leads of the generator and a trip which is arranged in a carrier and mounted on the armature shaft. The trip has two projections which engage corresponding lugs which are connected to, but insulated from, the front and rear blade of the switch. As soon as

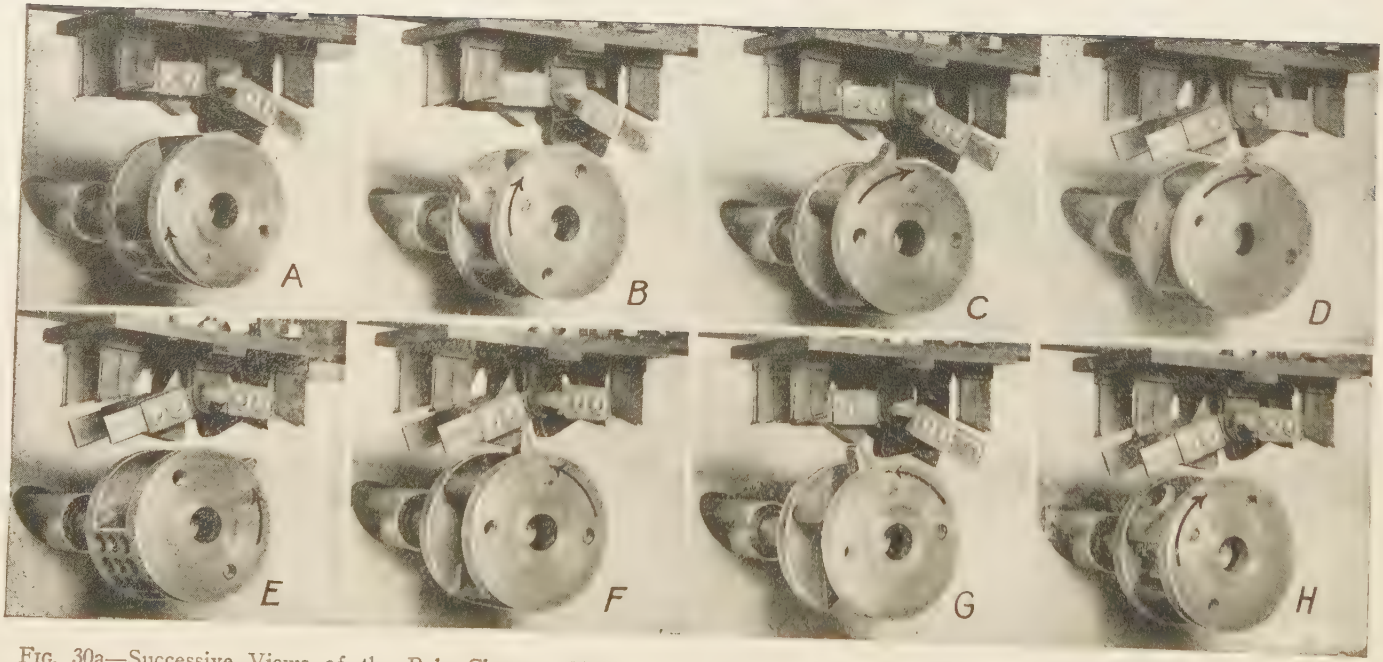


FIG. 30a—Successive Views of the Pole Changer Shown in Fig 30. Showing How the Pole Changing Switch Is Thrown by the Rotating Trip According to the Direction in Which the Armature is Rotating.

the switch is tripped, its throw is completed by a spring toggle which also holds the switch in place. The principle involved in this type of pole changer is as follows:

Starting with the car operating so that the armature rotates clockwise, the two-pole double-throw switch thrown to the right side and the field and generator current flowing in a direction as shown by the arrows in Fig. 31, the battery is receiving the charging current with the correct polarity.

Next assume that the same car is operated in the opposite direction. This means that the armature will rotate in the opposite

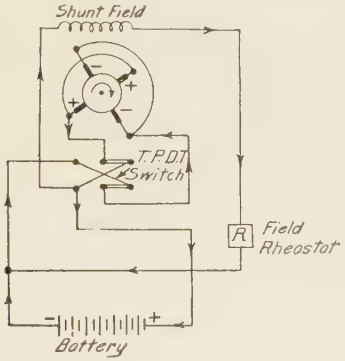


FIG. 31

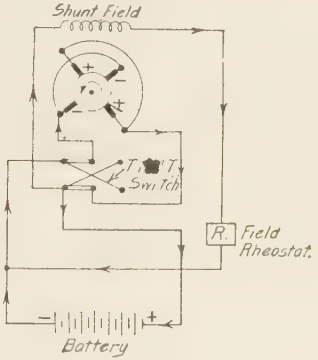


FIG. 32

FIG. 31—Clockwise Rotation—Switch Tripped to Right Side.
FIG. 32—Counter-clockwise Rotation—Switch Tripped to Left Side.

direction or counter-clockwise. As the armature turns over in the opposite direction the two-pole double-throw switch is tripped to the left side and when the generator builds up the current will flow through the field and to the battery as shown by arrows in Fig. 32.

Note that in Fig. 31 and Fig. 32 the field and battery current flow in the same direction but that the polarity of the generator leads between the armature and pole changing switch reverses with the direction of rotation. There is one axle generator—known as the E. S. B.—that requires no pole changer. The electrical characteristic of this generator is such that the same polarity prevails regardless of the direction of rotation of the armature. This equipment will be described in a later chapter.

CHAPTER V

REGULATING APPARATUS FOR AXLE-GENERATOR SYSTEMS

There are two regulators in common use with the axle generator system—a generator regulator and a lamp regulator. There are, however, some systems that require no lamp regulation, but the majority of systems use both lamp and generator regulators. It would be rather confusing if an attempt were to combine every minute detail of the many types of regulators with the various car lighting equipments. The set of regulators used in this lesson will cover the general principles involved in the majority of car lighting regulators. In later lessons we will study each equipment individually.

Generator Regulator. The generator regulator, frequently known as the dynamo regulator, connects the generator to the car wiring, controls the generator voltage and current and the rate of battery charge. There are two methods of current regulation—the total current regulation and battery charge regulation.

Total Current Regulation. – If the generator regulator controls the total generator current it is said to be connected for total current regulation—meaning that the generator output is constant, regardless of the lamp load. For example, if the generator output were 65 amperes and the lamp load were 15 amperes, the battery would receive the difference, or 50 amperes, and when the lights were off, the battery would receive the total 65 amperes. Of course, the regulating and field coils take a few amperes, but this can be neglected at present for simplicity.

Battery Charge Regulation. If the generator regulator controls the rate of battery charge, it is said to be connected for battery charge regulation and its total generator output will be the sum of the battery charging current and the lamp load or an increase of output as the lights are turned on. For example, if the

battery current were regulated at 45 amperes and the lights off, the total generator output would be 45 amperes, and if the lights were switched on, adding a 15 ampere load, the total generator output would be 45 plus 15 or 60 amperes, neglecting the small regulating and field current as above.

Regulator Parts.—The regulator under consideration will be one connected for total current regulation and consists of the fol-

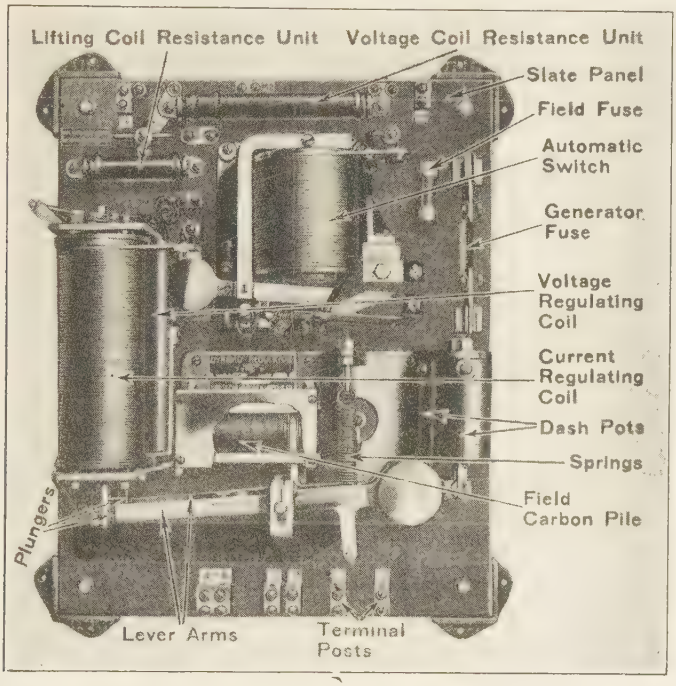


FIG. 33—One Type of Dynamo Regulator Panel.

lowing: A slate panel upon which is mounted an automatic switch, field carbon pile, voltage regulating coil, current regulating coil, field and generator fuses, and the necessary dash pots, plungers, lever arms, resistance units and the terminal posts, as shown in Fig. 33.

The function of the slate panel is to carry the various regulating parts, slate being a non-conductor and therefore is well suited for this purpose.

The automatic switch, Fig. 34, connects the generator to the

car wires and to the battery. This switch consists of two coils—a lifting coil and a series coil, an iron core, a movable iron armature, and two sets of contacts—copper and carbon. The *lifting coil* is connected at all times across the generator brushes and closes the switch when the generator voltage is slightly in excess of the normal battery voltage. The *series coil* holds the switch after it has been closed by the lifting coil and also opens the switch when the generator voltage falls below the battery voltage.

The operation of the automatic switch is as follows: With no current flowing, the armature, Fig. 34, will be held down by its

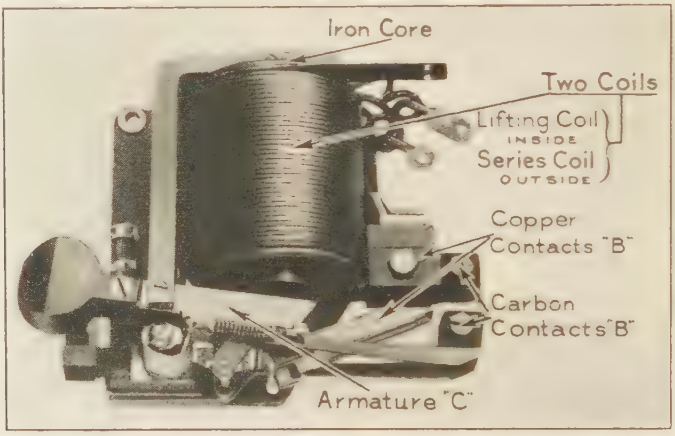


Fig. 34—Enlarged View of an Automatic Switch.

own weight and the main switch contacts will be open. As the generator voltage builds up, current flows through the lifting coil. When the generator voltage is slightly in excess of the battery voltage the lifting coil produces a magnetic flux in the iron core strong enough to raise the armature and close the main switch contacts *B*. The closing of the switch sends the generator current through the series winding of the automatic switch. The magnetic pull of the series coil is now added to that of the lifting coil and the switch is held firmly in a closed position. When the generator voltage falls below the battery voltage the current flows through the series winding of the automatic switch in the opposite direction. When the current is flowing in this direction, the magnetic effect of the series coil opposes the magnetic effect of the lifting

coil, and when they neutralize each other, there being no magnetic pull on the armature *C*, the pull of gravity forces the armature downward and opens the main switch contacts. The *copper contacts* are the main conductors. The *carbon contacts* protect the copper contacts by taking the arc when the switch is opened.

The *field carbon pile* is made up of a number of thin carbon discs and is connected in series with the field circuit, thus controlling the generator excitation. The resistance of this field carbon pile is varied by the movement of the plungers of the voltage and current regulating coils.

The *voltage regulating coil* is connected at all times across the generator brushes and controls the voltage of the generator by varying the resistance of the carbon pile. The coil controls the plunger whose arm acts directly on the carbon pile. The magnetic pull of the coil on the plunger is opposed by a spiral spring, Fig. 33. The spring is adjusted so that it will balance the magnetic pull of the coil on the plunger when the generator voltage is normal. For example: With no current passing through the coil, the plunger is pulled to its extreme downward position, compressing the field carbon pile. This condition remains while the generator voltage is normal or below normal. Should the generator voltage rise above normal, the magnetic pull of the coil will overbalance the pull of the spring and move the plunger upward. The plunger moving upward raises the arm and releases the pressure on the field carbon pile. This increases the resistance of the field carbon pile, thereby lowering the generator field current. This, in turn, reduces the generator voltage, and when the generator voltage reaches its normal value, the magnetic pull of the coil and the pull of the spring are equal, and the plunger is held in balance.

The *current regulating coil,* Fig. 33, is connected in series with the main generator circuit and controls the generator current by varying the resistance of the field carbon pile. The current coil controls the plunger whose arm acts on the carbon pile. The magnetic pull of the coil on the plunger is opposed by a spiral spring. The spring is adjusted so that it will balance the magnetic pull of the coil on the plunger when the generator current is normal. For example, with no current passing through the coil, the plunger is pulled to its extreme down position by the spring and the field carbon pile is fully compressed. When the current begins to flow

through the current coil, the spring holds the plunger in its extreme down position until the current rises above its normal value. Then the magnetic pull of the coil will overbalance the pull of the spring and move the plunger upward. The plunger, in moving upward, raises the arm and releases the pressure on the field carbon pile. This increases the resistance of the field carbon pile, thereby lowering the generator field current, which in turn reduces

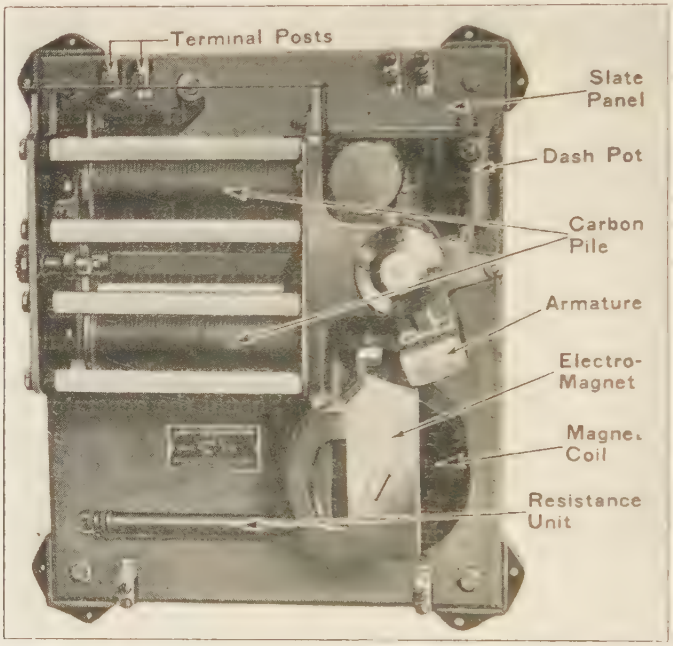


FIG. 35—One Type of Lamp Regulator Panel.

the generator current. When the generator current reaches its normal value, the magnetic pull of the coil and the pull of the spring are equal and the plunger is held in balance.

Air *dash pots*, Fig. 33, are used to dampen the movement of the plungers and lever arms. The dash pot consists of a brass shell with a graphite plunger. A small hole is drilled in the side of the shell to permit the air to escape.

The *resistance units*, Fig. 33, are connected in series with the lifting coil of the automatic switch and the voltage regulating coil.

The resistance unit that is connected in series with the voltage coil is provided with a number of taps for shunting out sections of the unit. This provides a means of adjusting the generator voltage setting.

Some regulators have a field exciter unit, but to avoid confusion, this type will not be considered in this discussion of the subject.

Two fuses are provided on most regulators to protect the armature and field circuits. One, a small fuse, is connected in the field circuit, and the other, a much larger fuse, is connected in the main generator circuit.

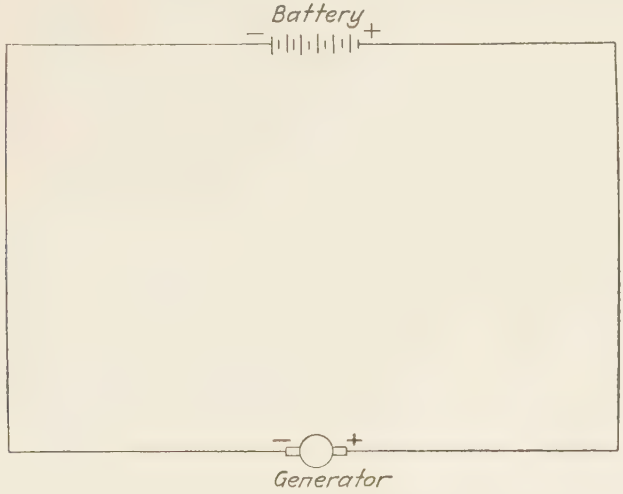


Fig. 36—Main Generator and Battery Circuit.

Terminal posts are located on the regulator panel to serve as a means of connecting the wires to the regulator.

Lamp Regulator.—The lamp regulator, Fig. 35, holds the lamp voltage constant when the generator or battery voltage rises above the normal rated voltage of the lamps. It consists of a slate panel upon which is mounted a carbon pile, an electro-magnet, a resistance unit and the necessary levers, dash pot, and terminal posts, as shown in Fig. 35.

The *lamp carbon pile* is made up of a number of carbon discs and is connected in series with the lamp circuits.

The *electro-magnet* consists of a coil with its core and armature. The coil is connected across the lamp mains, and operates on the

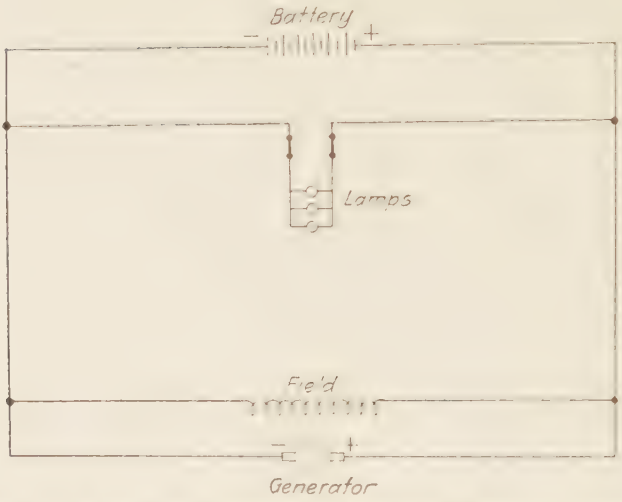


FIG. 37—Field and Lamp Circuit are Connected Across Generator and Battery Circuit.

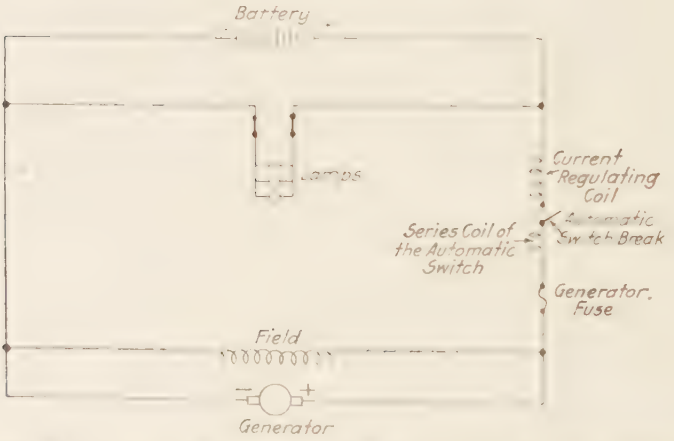


FIG. 38—The Generator Fuse, Series Coil, Switch and Current Regulating Coil are Connected in Series in the Main Circuit.

carbon pile as follows: With the lights off, no current flows through the magnet coil and a spring holds the carbon pile compressed. When the lights are switched on, the current to the lamps flows through the carbon pile. Current will also flow through the magnet coil. If the lamp voltage is above normal, the magnet becomes stronger and pulls the armature down, opposite the pull of the spring, and reduces the pressure upon the carbons. This increases the resistance of the carbon pile, and reduces the lamp voltage to normal. When the normal lamp voltage is reached,

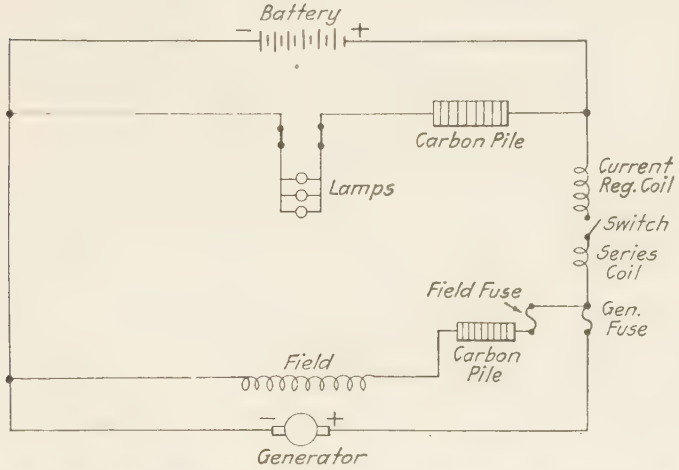


FIG. 39—The Field Fuse and Carbon Pile Connected in the Field Circuit—the Lamp Carbon Pile Connected in the Lamp Circuit.

the pull of the magnet and the spring will balance and the armature will remain in that position until there is another change in the lamp voltage.

The *resistance unit* is connected in series with the magnet coil. The *dash pot* is the air type and dampens the movement of the armature and levers. It is constructed the same as those described with the dynamo regulator.

Wiring Diagram.—With the knowledge of the wiring of the straight storage system and the axle generators which were described in previous chapters added to the description of the regulators given in this chapter, the wiring of an axle generator system can be easily understood. A general idea of the various connec-

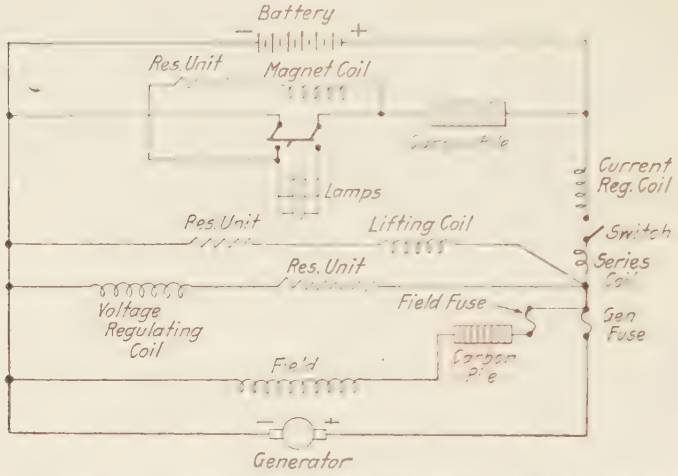


FIG. 40—Lifting Coil, Voltage Coil and Lamp Magnet Coil Circuits Added.

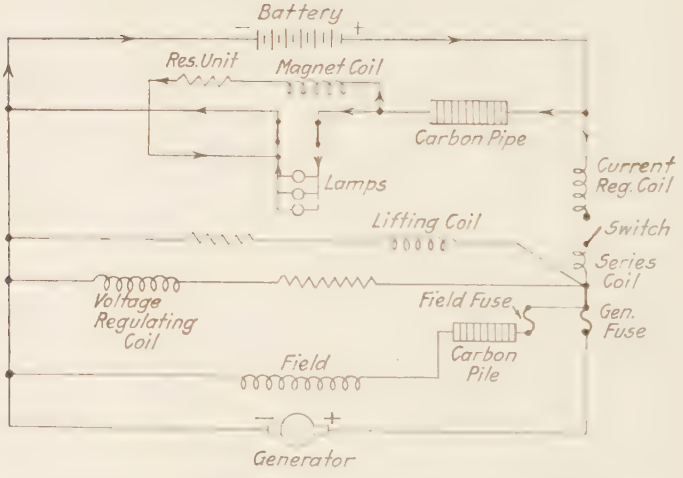


FIG. 41—Arrows Indicate Flow of Current from Battery to Lamp and Magnet Circuits—Car Standing and Automatic Switch Open.

tions and paths of the electric current can be obtained by drawing a simple wiring diagram step by step as follows: First, draw the main circuit connecting the positive side of the generator to the positive side of the battery, and the negative side of the generator to the negative side of the battery, as shown in Fig. 36. Second, connect the field and lamp circuit across the main circuit, as shown in Fig. 37. Third, connect the generator fuse, automatic switch series coil, automatic switch break and the current regulating coil in series with the main circuit, as shown in Fig. 38. Fourth, connect the carbon pile and fuse in the field circuit, as shown in

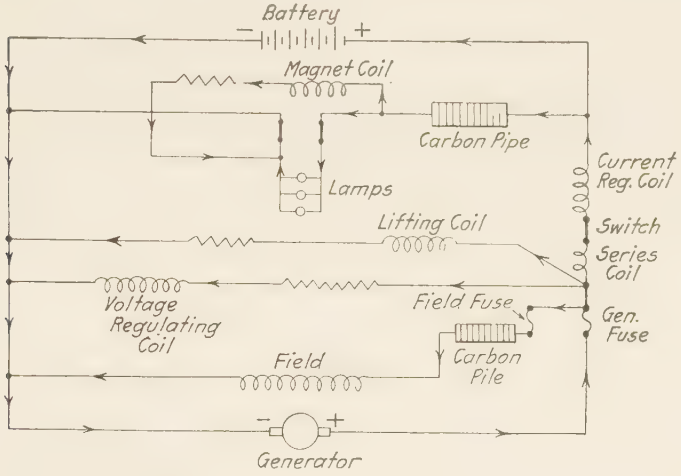


FIG. 42—Generator Operating at Full Load—Current Will Flow Through the Various Circuits as Indicated by Arrows.

Fig. 39. The positive side of the field circuit runs to the regulator panel, where it takes in the carbon pile and field fuse and is then connected to the positive side of the generator. Also connect the lamp carbon pile in the lamp circuit, as shown in Fig. 39. Fifth, complete the wiring diagram by connecting the three shunt circuits. These shunt circuits are—the lifting coil circuit, the voltage coil circuit, and the lamp magnet coil circuit. The lifting coil is connected across the main generator circuit in series with a resistance unit, as shown in Fig. 40. The voltage regulating coil is connected across the main generator circuit in series with a resistance unit and is also shown in Fig. 40. Both the lifting coil and the voltage

coil circuits are connected on the generator side of the automatic switch. The lamp magnet coil is connected across the lamp mains in series with a resistance unit, as shown in Fig. 40. The magnet coil circuit is controlled by the light switch, as one side of the circuit is connected to the load side of the switch. When the lights are turned off no current will flow in the magnet coil.

Flow of Current.– The arrows in Fig. 41 show the path of the current through the lamp and lamp regulator magnet coil circuits when the car is standing and the generator not operating. Trace the lamp current from the positive side of the battery to the lamps and back to the negative side of the battery. The current to the lamp regulator magnet coil flows from the positive side of the lamp circuit through the magnet coil and its resistance unit back to the negative side of the lamp circuit. Fig. 42 shows the flow of current with the lights on and the generator operating at full load. By following the arrows in Fig. 42 the generator current may be traced through the various circuits.

CHAPTER VI

TRANSMISSION OF THE AXLE GENERATOR

The history of car lighting by electricity reveals many experiments in an effort to develop for an axle generator a drive that is both practical and economical. The gear, chain, and flexible shaft drives have been tested but none of these have as yet been developed to a point where they are able to cope with the existing conditions as efficiently as the belt drive. It is true that many generators are driven by gears, chains, and flexible shafts in applications other than car lighting, but when a study is made of the method of suspending an axle generator, the lost motion in the running gear of cars, and the track and weather conditions under which a transmission in this service is required to operate, a problem is encountered which is by no means an easy one to solve.

The belt drive is, no doubt, the most practical, but by no means the most economical to maintain. It is this high operating cost that keeps the problem of economical transmission constantly before the car lighting engineer in an effort to perfect the belt drive or to develop an efficient design of direct drive. The progress made in the development of direct drives is outlined in Chapter XXI.

Belt Drive.—The belt drive consists of a belt equipped with a suitable fastener and two pulleys. One pulley, known as the axle pulley, is fixed to the axle, while the other, a generator pulley, is fixed to the armature shaft.

There are two classes of belting in general use—class 1, for free-speed generators, and class 2, for controlled speed generators. The Balata or rubber belting is used with variable or free-speed generators, that is, the generators that are regulated by an electrical regulator and when belt slipping is avoided as far as possible. The Balata-Aragoma belting is used with the constant speed

generators, that is, generators that are regulated by maintaining a constant speed through the slipping of the belt.

A Balata or rubber belt is a good belt for use with free-speed generators, but will not stand up so well with the slipping belt type.

The Balata-Aragoma belt will stand the slip and is a good belt for use with the controlled speed types.

The belting is used in various widths and thickness according to the size of the pulleys and the power they are to transmit. The length of the belts also varies with the length of the drive, but

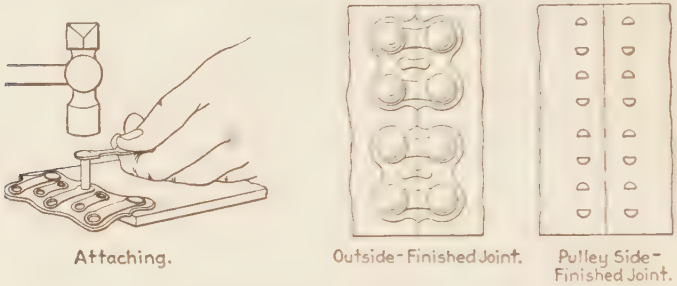


FIG. 43—"Crescent" Type of Belt Fasteners Riveted Over the Joint of a Generator Belt.

average 10 ft. for truck suspended types and 15 ft. for body suspended types.

Pulleys.—Axle pulleys are made in two halves and are fixed to the axle over a corrugated steel bushing. The bushing is held in place by four bolts, and likewise four bolts hold the axle pulley to the bushing. The bore of the bushing is straight or tapered, according to the size and shape of the axle at the point of application. The outside diameter of all bushings, however, is made standard so as to fit the bore of the axle pulley.

The generator pulley is much smaller than the axle pulley and bored to fit over the end of the armature shaft. The end of the armature shaft is threaded to accommodate a nut for holding the generator pulley in place. On a truck suspension the axle and generator pulleys ride with their centers in line, both on straight and curved tracks, therefore a generator pulley with straight flanges, and an axle pulley with straight or no flanges is used. Armature pulleys are made of pressed steel, cast steel, malleable iron, cast iron and various composite structures, but cast iron is the

most generally used. Pulleys for body-hung machines are equipped with special flanges.

The generator pulley is crowned and equipped with flanges—straight flanges for truck-suspended generators and tapered flanges for body-hung generators.

Belt Fasteners.—There are four different types of belt clamps in general use—Crescent, Jackson, Alligator and Walker.

The Crescent belt fastener consists of one or more thin steel plates which are held in place by copper-clad steel rivets. The rivets are made long enough to allow for the thickness of the belt, thickness of plate and for proper clinch. In applying Crescent fasteners the ends of the belt are squared and the plates placed in

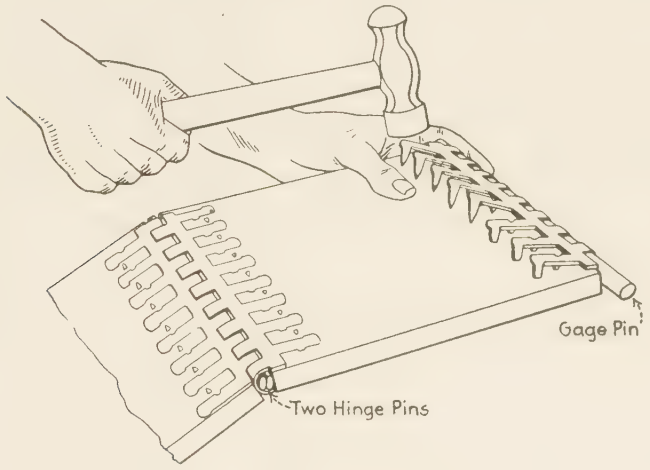


FIG. 44—Applying "Alligator" Type of Belt Fastener.

position and attached with rivets, as shown in Fig. 43. The rivets are applied by the use of a rivet holder and hammer, and are clinched so that the prongs spread across the belt. The size of the clamp and rivets varies with the size of the belt as follows:

Belt Size	Fastener	Large Shank
4" 4 ply	No. 65	Twelve ½" rivets
4" 5 "	" 65	" 9/16" "
5" 4 "	" 87	Sixteen ½" "
5" 5 "	" 87	" 9/16" "

This clamp is used with belts on truck-suspended generators that have a small truck clearance.

The Alligator belt fastener, Fig. 44, is clinched to the ends of

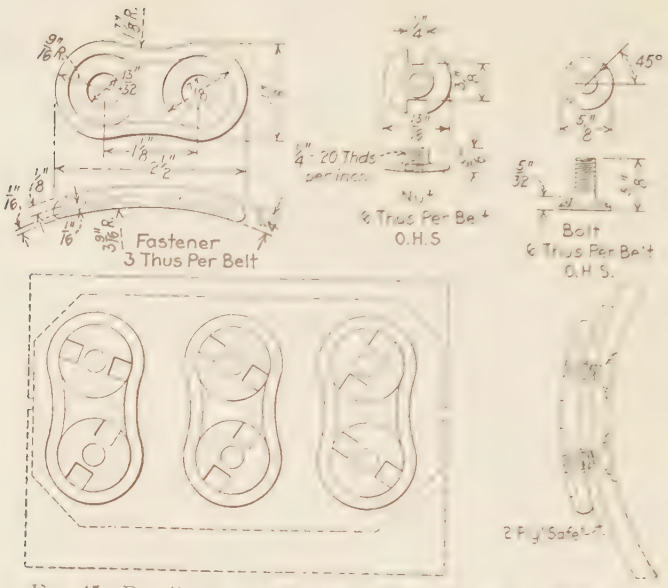


FIG. 45—Details of the "Jackson" Type of Belt Fastener.

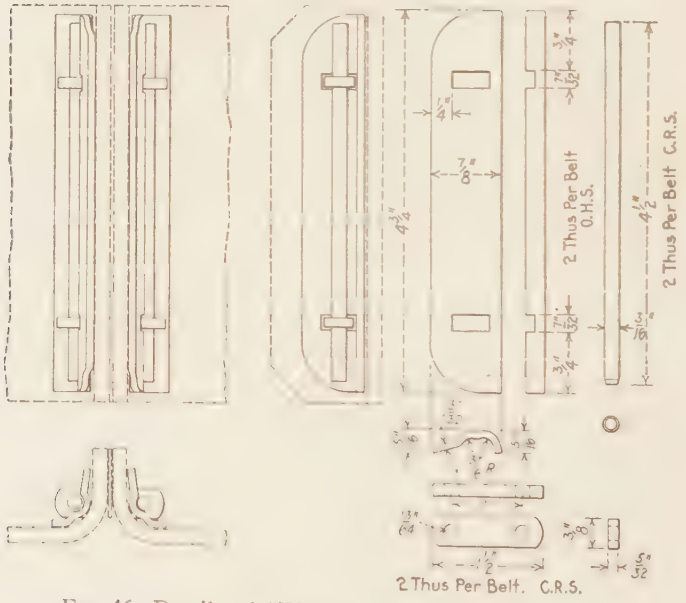


FIG. 46—Details of "Walker" Type of Belt Fastener.

the belt by a double row of teeth and is connected by the use of two steel pins, forming a hinged joint. In applying the Alligator belt fastener, the ends of the belt are cut square and the lacing is held over a gage pin and clinched to the end of the belt with a hammer, as shown in Fig. 44.

The following sizes are used with the various size belts.

Belt Size	Size of Fastener
4″–4 ply	No. 35
4″–5 ply	" 45
5″–4 ply	" 35
5″–5 ply	" 45

The Alligator is a good clamp for belts with truck-suspended generators as it requires but little belt clearance. It has an advantage, too, in the fact that a belt equipped with this type of clamp can be applied and removed in a short space of time.

The Jackson belt fastener consists of three metal straps and a canvas liner or safe. In applying the Jackson belt fastener the ends of the belt are squared and butted together and then the safe and strap are bolted in place as shown in Fig. 45. The Jackson belt fastener may be used with belts on both body and truck-suspended generators if there is sufficient belt clearance.

The Walker belt fastener consists of two metal plates, two links and two hinge pins. In applying this fastener, the ends of the belt are squared, then a line is drawn square across the belt 1 inch from each end. On these lines holes are punched for the fasteners. Fig. 46 shows the arrangement of this fastener. The size of the Walker fastener varies with the size of the belt as follows:

Belt Size	Fastener
4″–4 ply	No. 21821
4″–5 ply	" 21822
5″–4 ply	" 22655
5″–5 ply	" 22561

The Walker is a good fastener for belts with body-hung generators. When a car rounds curves, the pulleys are out of line and cause the belt to ride the pulley flanges. This requires a fastener that will allow the belt to be flexible and bend under the clamp in this action.

Belt Tension.—The belt tension on a controlled-speed generator is set so that the belt will slip at a predetermined speed. The belt

tension on a truck suspension is adjusted so that the belt will not slip because slipping in this case would cause the regulator to pump and flicker the lights.

Generator Suspensions. Generator suspensions, of which there are many types, are all provided with some means of applying the proper tension to the belt. These suspensions, although they vary extremely in design, may be divided into two general classes—body type and truck type. That is, every generator suspended from the truck, whether it be a two point, four point or

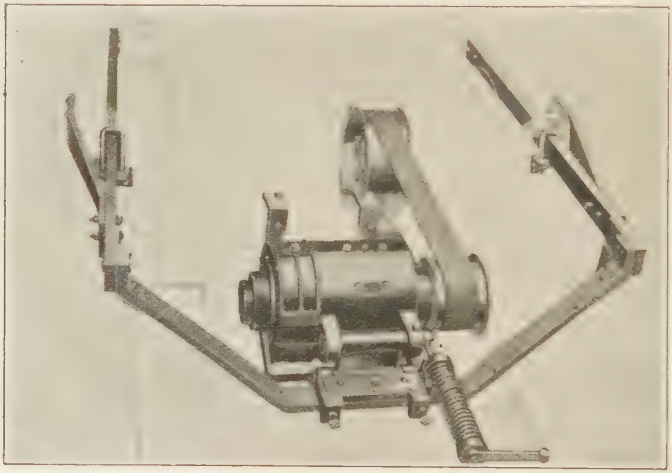


FIG. 47—End View of Truck Suspension Showing Pulley and Belt.

rigid suspension, is a truck-suspended generator. Likewise a generator suspended from the car body regardless of the design of the suspension is a body-suspended generator.

The following description of a truck suspension brings out a few points in comparison between truck and body suspension on a belt tension and belt life.

Truck Suspension. The truck suspension, Figs. 47 and 48, consists of a frame carried on two bars which are supported by the truck. The generator is provided with four lugs *C*; these lugs are drilled for two supporting shafts *D*, which pass through the lugs and through solid links *A*, the links being as long as the distance between the lugs. The lower end of each link is supported

by a shaft which passes through the link and supporting frame *B*. No wear can occur on the generator lugs or on the supporting frame, since the shafts are locked and cannot turn in the lugs or supporting frame; the turning motion being confined to the bushings in links *A* on the shafts. This arrangement provides a parallel suspension which has the points of support below the generator..

A very important feature of this type of suspension is that it maintains constant belt tension, even when the belt stretches as much as six inches. A tension spring bracket is bolted to the supporting frame and the tension rod *F* is secured to the end of the

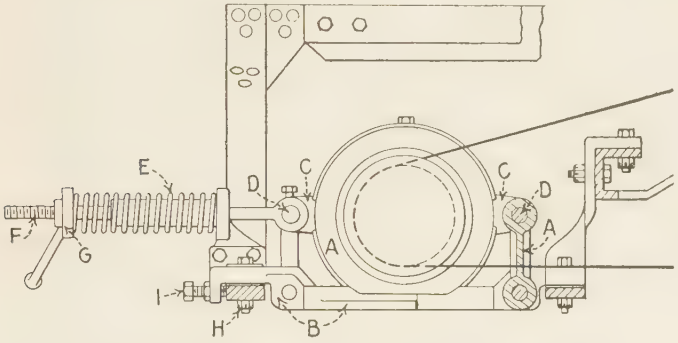


Fig. 48—Diagrammatic View of Truck Suspension.

shaft *D* with a tension spring *E* held at a proper predetermined tension by the nut *G*. Excessive belt strains, which are sometimes considered necessary to prevent the belt slipping when the tension decreases due to the belt stretching, are eliminated by this design. The nut *G* cannot be screwed beyond a predetermined position on the rod *F*, which limits the amount of tension an operator or inspector can apply. When the links *A* are in a vertical position the belt tension is due only to the pull of the spring *E*. If the belt is of such a length that the links are inclined away from the truck, a part of the weight of the generator is added to the belt tension, the amount depending upon the distance the generator is off the vertical. In moving the distance the tension spring is somewhat released and gives less pull. The design is such that the loss of tension in the spring is equal to the additional tension due to the

generator weight, and the total tension on the belt remains constant. If the links are inclined toward the truck, the weight of the generator is subtracted from the increased spring tension, and the belt tension is still maintained constant. All parts of the suspension subject to wear are lubricated, grease pockets with felt retaining washers being provided for all such parts.

The arrangement for lining up the generator with the car axle is simple and easily operated. The supporting frame *B*, Fig. 48, is secured to the suspension irons by six bolts *H*. The center bolt on the front side, or side farthest away from the truck, passes through a round hole in both the supporting frame and suspension

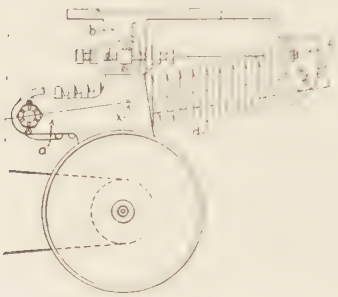


Fig. 49—Position of Dynamo When Distance Between Axle Pulley and Suspension is Shortened.

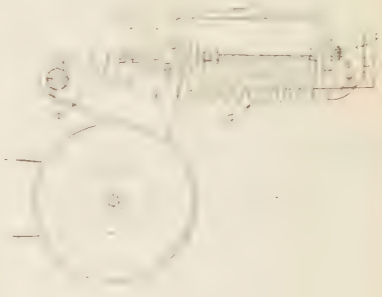


Fig. 50—Position of Dynamo When Distance Between Axle Pulley and Suspension is Lengthened.

iron. The holes in the supporting frame for the other five bolts are slotted so that the whole frame *B* can be swung around the center bolt. To line up the generator, it is only necessary to loosen all the bolts, line up the machine by means of the two adjusting bolts *I*, and lock it securely in position by means of the bolts *H*.

Inspection of the dynamo or removal of pulley, armature or heads, whenever necessary, is facilitated by the absence of any long supporting bars, thus giving clear space around the generator as will be noted by referring to Fig. 47. This illustration also shows that one side of the suspension is supported by a cross member fastened to side irons extending from the truck ends, while the other side is held by a bracket bolted directly to the end sill. This is a good arrangement, since the weight of the generator is

distributed between the truck and side irons instead of having all the weight of the generator carried by the side irons.

Body Suspension.—A generator with a body type suspension is shown in Figs. 49, 50 and 51. Cast on the generator frame are the carrying lugs *A*, which are pivoted to the supporting lugs *B* on the suspension casting by the suspension bar *C*. The suspen-

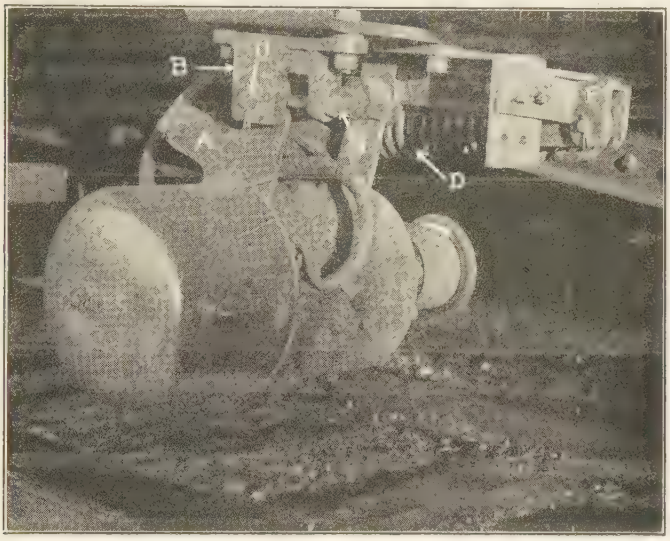


FIG. 51—Body-Hung Generator.

sion casting is to be bolted to a suitable plate secured to the car body.

Belt tension is maintained by the weight of the generator and by the tension spring *D*, which engages at one end with a lug *A* on the generator frame and at the other end with the bracket *F*, fastened to the suspension casting. The parts are so designed that the sum of these two varying factors is constant.

When the generator is hanging so that its center of gravity is directly under the supporting bar *C*, as in Fig. 49, the weight adds nothing to the belt tension, but the spring *D* has its greatest effect, since the leverage on which the spring acts—the distance between *C* and *X*—is greatest. If the generator is swung, as in Fig. 50,

the weight of the generator is giving tension, but the pull of the spring is decreased as the leverage CX is shortened; the sum of the two tensions being the same as in the first position. Ample latitude is provided between the two extreme positions of the generator, Fig. 49 and Fig. 50, to take care of belt stretch and the variation in distance between the dynamo and axle when the car is on a curved track.

The tension spring, Fig. 52, is assembled on a carrier, under the proper tension, so that to apply it to the suspension, it is only necessary to slip the pin secured to the lugs A through the hole G, and another pin through the hole H, and corresponding holes in

Fig. 52—Tension Spring Assembled on Carrier.

the suspension bracket F. This gives ease of application and assures the constant tension.

The arrangement for lining up the generator with the car axle is simple. The hole in one of the lugs B, Fig. 51, for the supporting bar C is slotted and the position of the bar can be adjusted and locked by means of the bolts I.

Fig. 51 shows the generator and suspension applied to a steel car and shows one simple method of attaching the suspension to the car, the clearance under the generator and its accessibility. This arrangement maintains the proper belt tension under all conditions and no adjustment of this belt tension device is required to maintain its proper operation.

The changing angle between the car and truck with this type of equipment as well as the variable distance between the centers of the car axle and the generator shaft caused by the car rounding curves, are adequately taken care of by maintaining constant belt tension with any position of the generator. This prevents excessive belt tension when the distance between centers is lengthened

and eliminates belt slipping when the distance between the centers shortens.

Comparison of Generators.—In striking a comparison between the truck and body suspensions, there are many things to be taken into consideration. Those who have studied the use of axle driven generators for car lighting, appreciate that the application of the generator to the car truck presents many problems, and that these problems are increasingly difficult to solve with the advance in design of steel trucks and car bodies. The deep center sill, almost universally used on new cars, has limited the space available for the application of the generator to such an extent that it is difficult to obtain proper clearance for the belt and generator, and frequently the generator is placed so near the track that ice and snow seriously interfere with its proper operation.

The rigidity of steel trucks causes wear of all moving parts of the generator and its suspension. The maintenance of these parts of car lighting equipment is becoming an important item in operating costs. Car designers would gladly welcome the removal of the weight of the generator, and generator suspension from the car truck, and would be glad to be relieved of the many other problems arising from the use of truck suspended generators. These problems are directly responsible for the change of late years from truck to body suspensions.

A comparison between the body and truck suspension is very distinct in Fig. 53.

The body suspension has the advantage in that it removes the entire weight from the car truck. Of course, it is obvious that transferring the entire weight to the car underframe does not remove the entire weight from the truck, but distributes and absorbs it properly through the bolster springs. It removes the overbalancing weight from the car axle carrying the generator and suspension.

Fig. 53 shows the truck suspended generator very close to the road bed, where it is frequently hit by flying ballast and collects snow and ice. The body suspended generator here shown is so high above the track as to be out of all danger from snow and ice, and is also out of range of the dripping condensation from the traps on steam heating systems. It can also be noted that the belt clearance is increased in the body-suspended generator. This

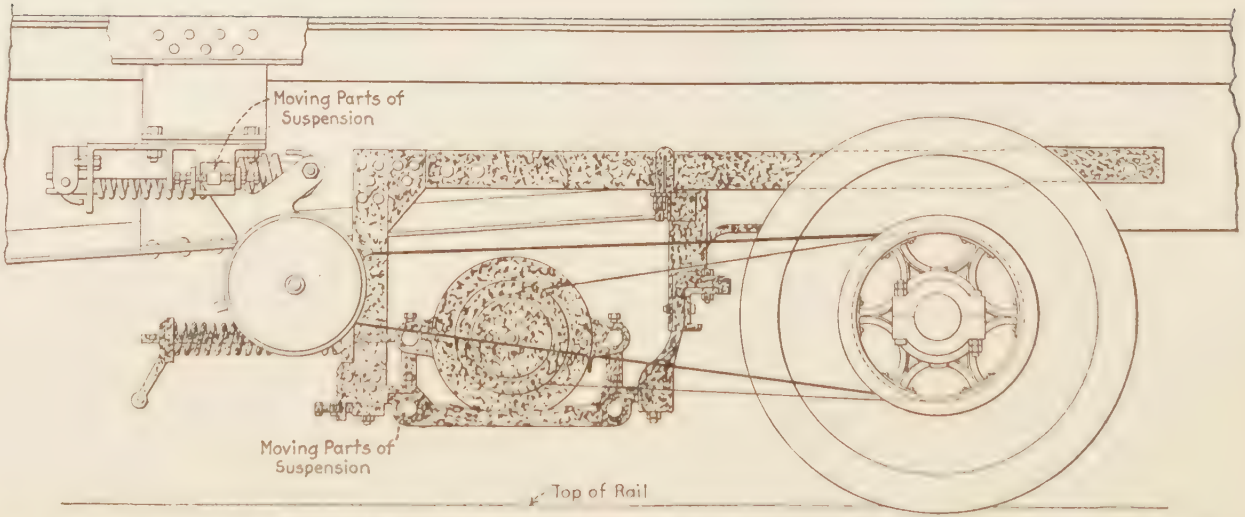


Fig. 53—Axle-Generator System. A Graphical Comparison of Body Suspended Type of Generator—Shown in Full Lines Applied to Car Underframe; and Truck-Suspended Type—Shown in Shaded Portion. Axle Pulley—Shown Applied to Car Wheel—is Common to both Types.

increased clearance is between the belt and end sill or brake rigging. It is also a well known fact among maintainers that a body suspended generator can be renewed or applied to a car with much more ease than with the truck type.

Life of a Generator Belt.—The life of a generator belt is governed by a number of factors, a few of which are track and weather conditions; size of pulleys, alinement of pulleys, and lost motion in running gear of cars.

Slipping of the belt is very often caused by the following:

1. Water sprayed from track tanks.
2. Steam escaping from steam drips.
3. Rain and snow.
4. Cinders and gravel embedded in the surface of the belt.
5. Action of hot and cold weather upon composition of belt.

Therefore, whenever the conditions cause the belt to slip, the heat thus generated by the friction of the belt on the pulleys injures the belt.

Size of Pulleys.—The smaller the diameter of the pulley, the less the area of belt contact; the smaller the belt contact the greater will be the tension to transmit the same power. Also, the smaller the pulley the sharper the bend in the belt; the sharper the bend, the greater the stress upon the fibre of the belt. Therefore the size of the pulleys has a decided bearing upon the life of the belt.

Alinement of Pulleys.—The proper alinement of pulleys is a big factor in the performance of the belt. This holds good on both truck and body suspended machines. If the pulleys are out of line the result will be as follows:

1. Belt will ride over flange, become entangled with brake rigging and lost.
2. Belt will ride hard against pulley flanges and ravel along the edge, break back of fasteners and be lost.
3. Belt will ride flanges and slip back lengthwise to the face of the pulleys causing unnecessary wear and tear on the belt fibres.

Lost Motion of Running Gears.—There is a certain amount of play between the various bearings and parts of the truck, and also in the movable parts of the generator suspension. This play will

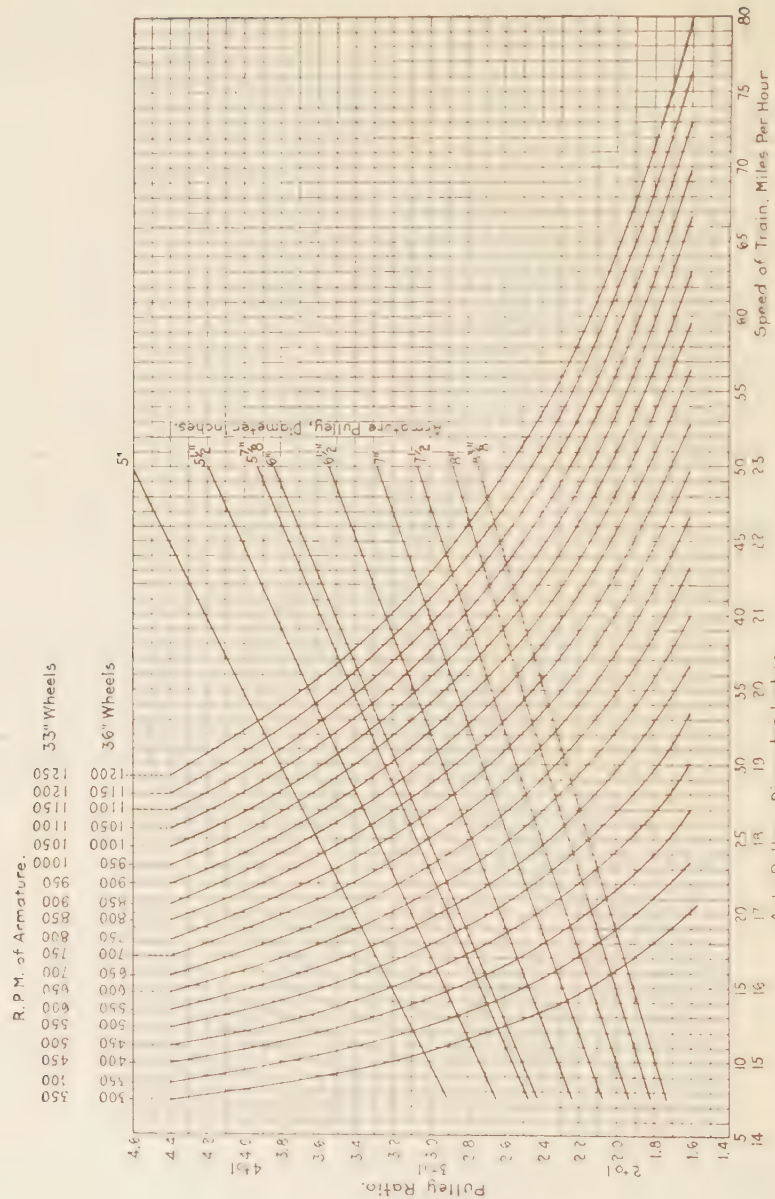


FIG. 54.—Transmission Graph Which May Be Used to Determine Cutting in Speed.

increase with the length of the service rendered by the car and in time, if not checked, will have a serious effect upon the life of the belt. The excess play will throw the pulleys out of line, the bad results of which have already been stated. It will also vary the belt tension as the play is taken up and released by the action of the brakes. If this action releases the tension the belt will sag and strike the brake rigging and end rail, and if it increases the tension it is apt to snap the belt or break the fasteners.

Maintenance.—Considering the fact that a 15 ft. belt is worth approximately eight dollars, and a belt fastener is only worth fifty cents, it pays to examine the belt fasteners regularly and renew them when they are found to be defective.

Also it has been stated that the required tension depends upon the area of contact surface on the pulleys. Therefore, if the belt fastener is not applied at right angles to the edge of the belt, the point of contact will be at one end of the clamp and likewise the tension, instead of being distributed evenly along the clamp, will be centered at one end. Then as the tension is increased to compensate for the small area of contact the clamp will give way at one end and when this occurs, the belt will ride the pulley flanges and be lost. Therefore, it is of greatest importance that the ends of a belt be cut square with its length and also that the fasteners are applied square with its length.

Calculating Speed of Axle Generators. –In calculating the cutting-in and minimum full-load speed of an axle generator there are four things that must be considered:

1. Diameter of car wheel.
2. Diameter of axle pulley.
3. Diameter of armature pulley.
4. Cutting-in and minimum full-load speed of the armature.

The cutting-in and minimum full-load speed of the armature varies with each type of equipment, and is easily obtained from the manufacturer.

The following is one way to find the speed of the car in miles per hour, when the automatic switch closes.

Knowing the r. p. m. of the armature when the automatic switch closes, divide it by the pulley ratio—the ratio of the diameter of the axle pulley to the diameter of the armature pulley; the result will be the speed of the axle pulley in r. p. m. when the

switch closes. This value will also be the speed of the car wheel in r. p. m. because the axle pulled is bolted to the axle and rotates the same number of revolutions as the car wheel. There are 60 minutes in one hour, therefore multiply this value by 60 and the result obtained will be the speed of the wheel in r. p. h. when the automatic switch closes.

Next, multiply this value by the circumference of the car wheel in feet and the result will be the speed of the car in feet per hour. There are 5,280 feet in one mile, and this value can be changed to m. p. h. by dividing by 5,280.

For example, figure the train speed when the automatic switch closes (34 volts) on the following equipment:

Cutting-in speed of armature—250 r. p. m.

Size of axle pulley—18 inches.

Size of armature pulley—8 inches.

Size of car wheel—36 inches.

Pulley ratio is 18/8 or 2¼.

Circumference of 36 inch wheel is 9.425 feet.

R. p. m. of armature ÷ pulley ratio = r. p. m. of car wheel.

250 ÷ 2¼ = 111.1.

R. p. m. of car wheel × 60 min. = r. p. h. of car wheel.

111.1 × 60 = 6,666.

R. p. h. of car wheel × circumference of car wheel = speed of car in feet per hour.

6,666 × 9.425 = 62,827.

5,280 ft. per mile.

62,827 ÷ 5,280 = 11.9 or approximately 12, which is the speed of the car in m. p. h. when automatic switch closes.

There is a much quicker method of figuring this, but more advanced. The easiest way is to refer to the transmission graph, Fig. 54. In this the cutting-in speed is figured to be 12 miles per hour. If the cutting-in speed of the armature were just double, or 50 r. p. m., the same car would be traveling just twice as fast, or 24 miles per hour when the generator cut in. Check this by referring to the transmission graph. Find the 500 r. p. m. line in the 36 in. wheel column and follow this line to the intersection of the pulley ratio which is 2.25 and then downward. In the speed of train in miles per hour column, we find 24, which shows the calculation to be correct.

CHAPTER VII

TRAIN LIGHTING STORAGE BATTERIES—I

The history of the development of the storage battery is interesting. From the beginning of the art, the aim has been to produce an electrolytic cell in which electrical energy may be stored as chemical energy until ready for use. This cell must return at any time all or any part of the electrical energy put into it. It must also be in its original state when completely discharged.

In 1801 Gautherot discovered that silver or platinum wires used for decomposing water by the passage of an electric current would send the current in a reverse direction when placed on discharge.

In 1834 Faraday discovered that lead peroxide deposited by acetate of lead would give a current in the opposite direction from that originally causing the decomposition.

In 1854 Sinsteden discovered that plates of lead, silver and nickel in a voltameter would produce reverse currents.

In 1860 Plante discovered that two sheets of lead separated and immersed in acid would send a current in a reverse direction when discharged.

In 1881 Charles H. Brush, in America, and Camilla A. Faure, in France, each experimenting independently, produced the lead battery pasted plate.

In 1908 Thomas A. Edison, after years of study, developed the nickel-iron alkaline storage cell.

The storage battery is a very essential part of each system of car lighting by electricity. This is true because the storage battery is the only means of storing electric power.

In the straight storage system, the storage battery is the only source of electric supply; this system is completely disabled when the storage battery fails.

The head-end system, when equipped with a storage battery of

sufficient capacity to carry the lamp load for a reasonable length of time, will survive a turbine or generator failure en route.

The axle-generator system continues to function after the loss of a generator belt, a defective generator or generator regulator, often without the knowledge of the train crew or any inconvenience to the passengers. The storage battery furnishes the electricity to light the car the instant the generator fails; should

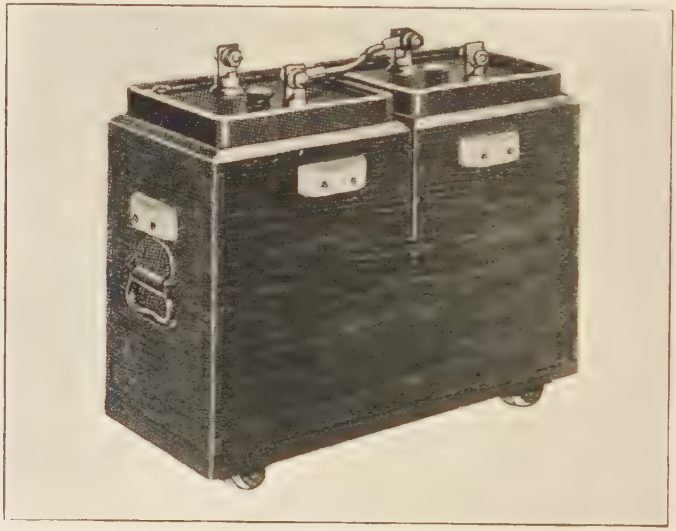


FIG. 55—Two-Cell Unit of a Lead-Lead Type Battery With Closed Wooden Tank and Rubber Jars.

the storage battery also fail, the car will be thrown into darkness the moment the train stops and when the car is again in motion, the generator will not build up unless it is provided with residual magnetism in the pole pieces. The generator furnished with some axle lighting equipments is excited by the storage battery through a unit of high resistance.

Train lighting batteries are designed to operate and give service under railroad conditions. This means that the battery must withstand rough handling, due to the bumping of the cars, etc., that it must stand a wide range of temperature due to climatic conditions, and also be able to overcome the effects of neglect, such as remaining in a discharged condition for long periods.

The word "storage" suggests that electricity is stored in the battery, but this is not so. A chemical change occurs in the battery which under the proper conditions can be reversed to produce electricity. There are two distinct types of train lighting batteries —the *lead-lead* type battery, and the *nickel-iron or Edison* battery. In describing each type the same general outline will be used so that the reader may make a direct comparison.

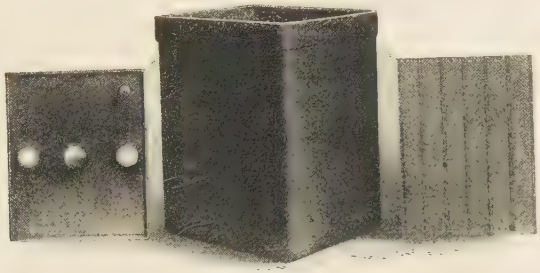


FIG. 56—Rubber Jar With Soft Rubber Cover and Double Ribbed Rubber Separator.

Lead-Lead Train Lighting Batteries.—A lead-lead train lighting battery is a number of cells each of which is a unit consisting of the following main parts:

1. Containing vessel with cover.
2. Positive and negative groups of plates.
3. Electrolyte.
4. Separators.
5. Connectors.

Types of Containing Vessels.—The containing vessel in general use is a two-compartment tank, resting on porcelain rollers or buffers. There are three general types of these tanks:

1. The closed wooden tank and rubber jars.
2. The closed wooden tank and lead linings.
3. The slatted wooden crate and lead linings.

The containing vessel for the two-cell unit type, as shown in Fig. 55, is a double compartment oak tank, resting on four porcelain rollers and having a wooden partition separating the two compartments. A rubber jar, shown in Fig. 56, is placed in each

compartment and the space between the jars and the oak tank is filled with an insulating compound. The oak tank is provided with porcelain side and end buffers. The buffers insulate the tank from the sides of the battery box and from each other.

The containing vessel for the two-cell unit type, as shown in Fig. 57, is a double compartment wooden tank, resting on four porcelain buffers, and having a wooden partition separating the two compartments. A lead lining, Fig. 58, is placed in each com-

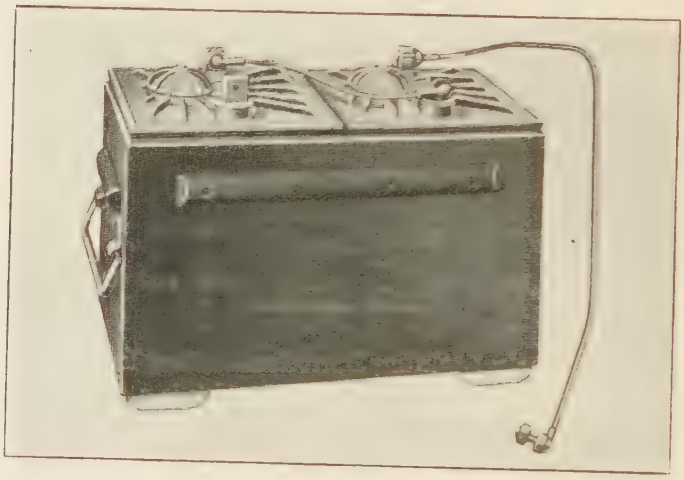


FIG. 57—Two-Cell Unit of a Lead-Lead Type Battery With Tank Crate and Lead Lining.

partment and the space between the lead lining and the wooden tank is filled with insulating compound. This compound protects the lead lining against pitting from electrolytic action, and facilitates the removal of the lining from the tank. The wooden tank is provided with wooden side and end buffers which insulate the tanks from the sides of the box and from each other.

The containing vessel for the two-cell unit type, as shown in Fig. 60, is a double compartment wooden crate, resting on four porcelain buffers, and having a wooden partition separating the two compartments. A lead lining, as shown in Fig. 58, is placed in each compartment and tar sheets are placed between the lead lining and the wooden crate.

Porcelain bottom rests, as shown in Fig. 58, are designed to

support the positive and negative groups a sufficient height from the bottom of the cell to allow for any sediment that may accumulate.

The containing vessel covers are generally made of soft rubber, as shown in Fig. 56, or of lead, as shown in Fig. 59. The space between the rubber cover and the rubber jar or lead lining is filled with sealing compound to hold the cover in position and to prevent the leakage of electrolyte. The lead covers of some of the containers are lead burned to the lead lining. The space around each terminal is sealed by slipping a soft rubber bushing

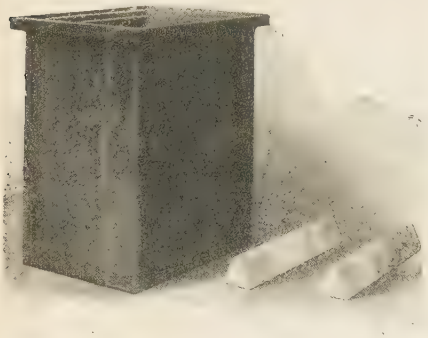


Fig. 58—Lead Lining, Porcelain Rests.

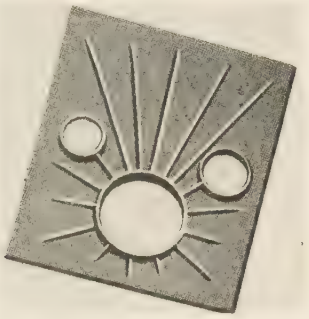


Fig. 59—Lead Cover.

over the terminal, and pressing it tightly into the hole in the cover. These spaces must be securely sealed, otherwise the tanks would soon become acid soaked and grounded, and acid spray would corrode the exposed metal parts of the battery box. The use of rubber bushings also serves to reduce the breakage of covers. Each cover is provided with a vent plug to allow the gases to escape while the battery is charging. By removing this vent plug the electrolyte may be inspected and the height of the liquid may be ascertained and its specific gravity corrected when necessary.

Positive and Negative Groups of Plates.—In the lead-lead storage battery both positive and negative plates are of lead. Two types of lead plates are in general use—the *Planté,* in which the active material is formed from the plate itself, and the *Faure,* in which a lead compound, transformed during the manufacture of

the battery into active material, is pasted on the plate. The Faure type of plate is seldom used in car lighting service.

The capacity of storage batteries depends upon the amount of active material exposed to the action of the electrolyte. It is advisable to make the active material in a thin layer and obtain the volume required by increasing the surface or area. There are several reasons for this, but it is chiefly due to the fact that the porosity of the material of the positive plate is insufficient to contain enough of the sulphuric acid of the electrolyte to thor-

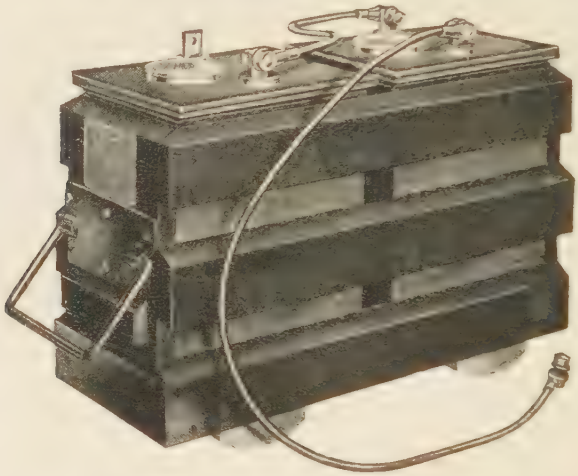
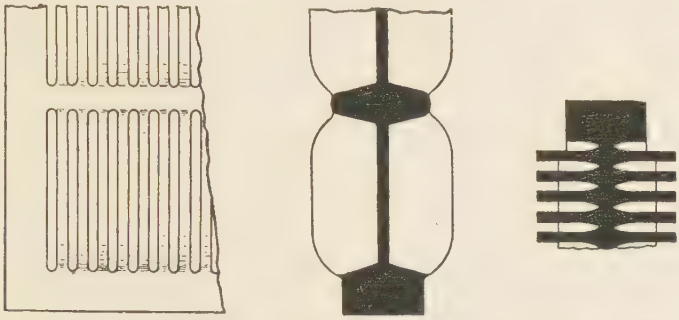


FIG. 60—Two-Cell Unit of a Lead-Lead Type Battery With Slatted Crate and Lead Lining.

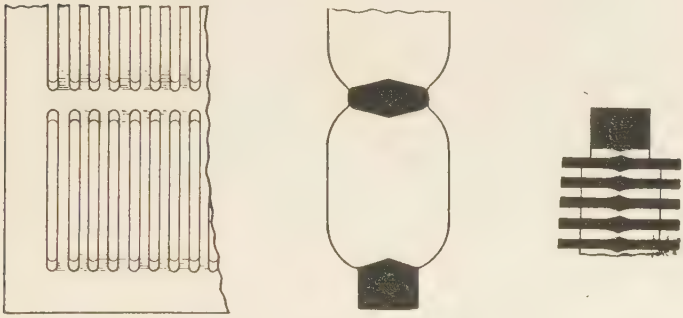
oughly discharge the plate, therefore the deficiency must be supplied by diffusion, which takes place slowly. To obtain a given capacity with a thin layer of active material it is evident that the surface exposed to the action of the electrolyte must be large. For these reasons the plates are cast of cellular construction, or corrugated, grooved, or ribbed on the surface for the purpose of increasing the superficial area and so increasing the amount of active material in contact with the electrolyte—see Fig. 61.

The life of the battery depends upon the amount of reserve lead available in the plate structure which may be converted into active material as the original active material is lost by shedding. Assuming that several plates of the same type have the same

weight of lead, it is plain that the plate with the greatest area will also have the least thickness of reserve lead per lamination, that is, increasing the number of laminations decreases their thickness. The design of the battery plate therefore involves a comparison



"H" Structure Employed in National Positive



"U" Cellular Structure Employed in National Open Negative

FIG. 61—Method of Construction Giving Increased Plate Surface.

between these conflicting conditions and it is also affected by the amount of local action, charging rates, etc.

Method of Forming the Plates.—The plates having been designed to give the desired amount of superficial area, they must now be electrochemically formed to produce the desired depth of active material on their surfaces. The plates are submerged in a dilute solution of sulphuric acid to which is added a small amount of nitric acid or other forming solution. Plain sheets of pure lead known as "dummies" are placed on each side of the

plates to be formed and a current from an external source is passed through the solution from the plates to the dummies.

The surfaces of the plates, under the combined action of the forming solution and the current, are changed from lead to a mixture of lead sulphate and lead peroxide, this operation being known as "forming," and this mixture of lead sulphate and lead peroxide at this stage being known as the "formation."

The forming may be carried on until any desired depth of active material is obtained, while the hardness of the formation

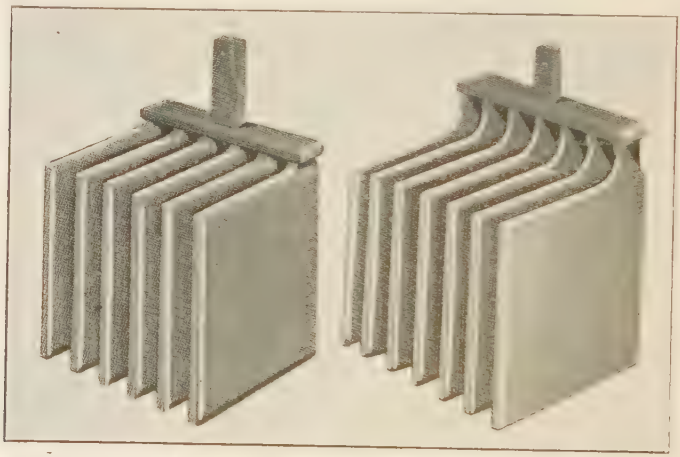


FIG. 62—Positive and Negative Groups. The Negative Group Contains One More Plate Than the Positive Group.

can be varied, by varying the rate of current flow and the density of the forming solution. This process converts all the plates into positives, but, on such as are intended for negatives, the formation is carried to a greater degree.

After being formed, the plates intended for negatives are placed in tanks containing dilute sulphuric acid, with dummies on each side of the plate, as before, and current from an external source is passed from the dummies to the plates. The lead peroxide on the plate, under the action of the current, is converted into spongy lead, or, in other words, the plate is converted into a negative.

The plates usually stand for some time in the stock room before being burned to their respective cross straps or bridges and

become more or less dried out. Consequently, after the plates are burned to the cross straps, set up with separators, and placed in the tanks, they must be very thoroughly charged to reduce the lead sub-oxide into which the spongy lead has been converted and to thoroughly develop the positive plates.

Elements in the Lead-Lead Cell.—The *positive* group, as shown in Fig. 62, is made up of a number of positive plates burned to a connecting strap or bridge. The Planté type of positive plate consists essentially of lead which has been treated by some mechanical process to greatly increase its superficial area. Its surface has been converted, by chemical or electro-chemical means, into lead peroxide. This lead peroxide has a rich chocolate

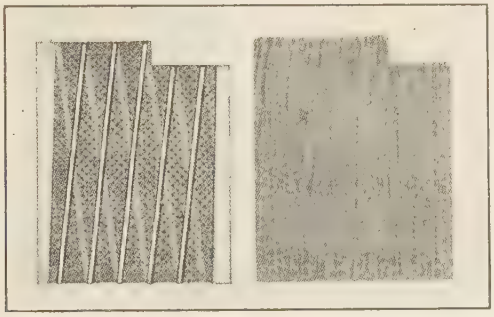


Fig. 63—Separators.

brown color when the battery is fully charged. The body of the lead serves as a support for the lead peroxide or active material, as a conductor for the current, and as reserve material to be converted into lead peroxide when the original active material is lost by shedding and falling to the bottom of the vessel.

The *negative* group, as shown in Fig. 62, consists of a number of negative plates burned to a connecting strap or bridge; the negative group always has one plate more than the positive group with which it is used. The negative plate is similarly treated to increase its superficial area and the surface is converted into active material. The active material in this case is spongy lead or lead which is very porous. The spongy lead has a slate gray color when the battery is fully charged.

The *separators*, Fig. 63, may be made of any insulating material

which prevents the negative and positive plates from coming into electrical or mechanical contact, but which does not prevent the electrolyte from reaching the plates. Furthermore, it must not be of such composition as to become affected by the electrolyte or contain substances injurious to the battery. Hard rubber is generally used for this purpose in the batteries for electrically lighted cars and is made up in the form of a thin sheet having numerous small perforations with several ribs extending across the sheet to strengthen it and at the same time to give the necessary separation between adjacent plates.

The *electrolyte*, or solution in which the groups are submerged in a containing vessel, consists of dilute sulphuric acid of a normal specific gravity of 1.220 at 70 degrees F., when the battery is fully charged. (The specific gravity of a liquid is the weight of that liquid divided by the weight of an equal volume of water.)

The two cells in the tank are connected together, positive to negative, by means of insulated copper wire. The terminals of adjacent tanks are also connected together by insulated wire connectors.

Theory of a Lead-Lead Storage Battery. – As it is chemical energy that is stored in the battery and not electricity, it is necessary, when explaining the action that takes place in the battery, to include chemical symbols, formulas and equations. Therefore an explanation of a few terms may help those who have no knowledge of chemistry. The symbols for the elements which will be used are as follows:

Elements	Symbols
Hydrogen	H
Oxygen	O
Sulphur	S
Lead	Pb.

These elements are combined into the following: Water, sulphuric acid, lead sulphate, lead peroxide.

The formula for water is H_2O, meaning that hydrogen and oxygen are combined to form water.

The formula for sulphuric acid is H_2SO_4, meaning that hydrogen, sulphur and oxygen are combined to form sulphuric acid.

$PbSO_4$ is the formula for lead sulphate, indicating a combination of lead, sulphur, and oxygen.

Similarly PbO_2 signifies that lead and oxygen are combined to form lead peroxide.

Action of Discharge.—On discharge the spongy lead (Pb) and lead peroxide (PbO_2) are converted into lead sulphate ($PbSO_4$) at the expense of some of the sulphuric acid (H_2SO_4) and in an amount almost exactly proportional to the ampere hours discharge; in addition some water (H_2O) is formed, which dilutes and decreases the specific gravity of the electrolyte.

The original chemical energy is decreased by an amount equal to the electrical and heat energies developed, the latter being relatively small.

Action on Charge.—On charge the reverse action takes place, the lead sulphate ($PbSO_4$), previously formed on discharge being converted back to spongy lead (Pb) in the negative plates, and to lead peroxide (PbO_2) in the positive plates, a certain amount of water being chemically combined, in again forming the sulphuric acid (H_2SO_4) and lead peroxide (PbO_2).

The lead storage battery therefore belongs to that class of batteries which are more or less reversible in their action. It is not completely reversible because of the heat generated and because of other actions which are as follows:

The chemical reactions taking place may be expressed by the following equations:

Reaction at positive plate:

(a) $PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O.$

Reaction at negative plate:

(b) $Pb + H_2SO_4 = PbSO_4 + 2H.$

Combined Reaction of positive and negative plates:

(c) $PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O.$

These equations are the fundamental equations of the lead storage battery.

Equation (c), read from left to right, is the equation of discharge, and shows the change of spongy lead and lead peroxide on the negative and positive plates respectively into lead sulphate and the formation of water from the hydrogen and oxygen of the electrolyte. Read from right to left this equation shows the reaction during charge.

Active Materials of a Lead Cell.—The active materials of a lead cell are not hard dense masses, but are crystalline in structure,

as will be readily apparent under a moderately strong magnifying glass. The crystals are more or less intermeshed, so that the masses are coherent. The chemical changes described do not take place completely throughout the crystals, but the action is more or less confined to their surfaces. Both the spongy lead and the lead peroxide crystals are electrical conductors, and the active masses are conductors because of the contacts of these crystals. The lead sulphate formed on discharge is, however, non-conducting. It is probably oxidized at the positive and reduced at the negative on charge, because of its solubility, though the degree of solubility is very slight. The difference between the lead sulphate normally formed on the discharge of a battery and the injurious sulphate which is sometimes evident, probably lies in the fact that the normal sulphate is composed of extremely minute crystals and is therefore more readily soluble, while the injurious sulphate is composed of relatively large crystals, and therefore soluble with difficulty. This injurious sulphate may be reduced to spongy lead by excessive charge, but is with difficulty or not at all to be directly oxidized to lead peroxide.

The tendency for small crystals to merge into larger ones, which is plainly seen in a saturated solution of copper sulphate, is an explanation of the manner in which the injurious sulphate is formed. This is one of the reasons why storage batteries should not be allowed to stand wholly or partly discharged for longer periods than is absolutely necessary under the service requirements.

It has been pointed out that the active materials are crystalline. The dilute sulphuric acid electrolyte fills the spaces between the crystals, that is the pores of the masses of active material. The porosity of the active masses is fairly high but varies with the method of formation. In practically no case is it great enough, however, to accommodate sufficient sulphuric acid for the complete conversion of the active materials. The deficiency of acid has to diffuse into these pores from the outside. The phenomenon of diffusion, as distinguished from convection, is extremely slow, and for this reason the practical thickness of the masses of active materials used is limited; a greater thickness is permissible for low discharge rates, as a longer time is then available for fresh acid to diffuse into the pores of the mass of the active material. Diffusion is greatly accelerated by increased temperature; for this

reason high temperatures increase the discharge capacity. Very high temperatures, however, are not permissible, as a corrosion of the positives is then more rapid.

The Limit of Discharge.—The limit of discharge capacity is largely set by the porosity of the active materials and the rapidity of diffusion of the acid into its pores. The extent of the conversion of the active materials into lead sulphate must also be limited as the electrical resistance increases considerably at the latter end of discharge.

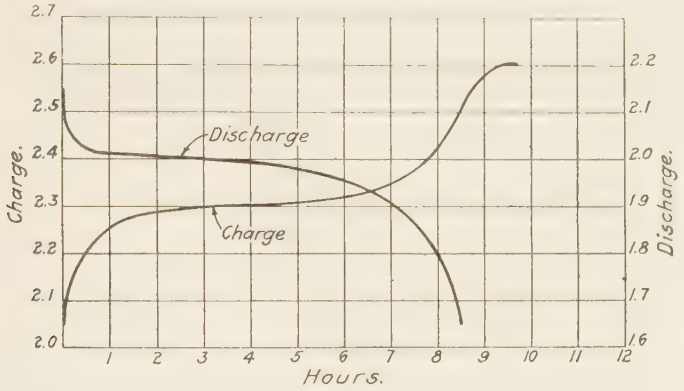


FIG. 64—Charge and Discharge Curves—Eight-Hour Rate.

Approximately, only thirty to fifty per cent of the entire amount of active material takes part in the reaction for the above reasons.

Difference Between the Electro-Motive Force and the Voltage at Terminals.—The electro-motive force of a lead battery, as distinguished from the voltage at the battery terminals, is dependent only on the strength of the electrolyte and its temperature, as long as any unconverted active materials are present. On open circuit a battery always shows a voltage of approximately 2.1 volts. The voltage at the terminals on discharge is less than this amount by the value of the various resistance voltage drops. These resistance voltage drops are:

1. The drop in the terminal lugs and grids of the plates.
2. The drop in the current path of the active material.
3. The drop in the current path in the electrolyte, both in the pores of the active material and outside of the plate.

If the battery is partly discharged, the open circuit voltage,

immediately after interrupting the current, is somewhat lower than the value given above, but it readily approximates this value as acid diffuses into the plates. For this reason open circuit readings are of no value in determining the state of charge of a battery. It has been shown that on discharge the voltmeter reading is the battery electro-motive force less the sum of the various resistance voltage drops.

On charge, the various resistance drops are still present, but must be added to the electro-motive force of the cell to give the impressed terminal voltage, that is, the voltmeter reading. This explains in part the difference of voltmeter readings obtained on charge and discharge. Fig. 64 shows charge and discharge curves of a lead battery when charged and discharged at the normal rate.

The lead sulphate formed on discharge occupies a greater volume than either the spongy lead or the lead peroxide, from which it is formed. In consequence there is an expansion of the active material which must be taken up either in its pores or by the grid. This must be cared for in the design of the plates as far as it is possible, and in service the battery should not be over-discharged if it can be avoided. Too great an expansion from the above cause results in growth and buckling of soft lead Planté plates or the breaking of the grids of pasted plates.

Sediment, or Shedding of Active Material.—The small lead crystals of the negative active material show a decided tendency to cohere and negative plates do not shed much active material unless considerably sulphated. The crystals of lead peroxide of the positive active material, however, are hard and are not as coherent as those composing the negative material. These lead peroxide crystals gradually break up into smaller crystals with successive discharges, and finally become so small that they have no coherence. Gassing of the plates on overcharge dislodges such crystals, and these, together with any loose crystals of sulphate which may have formed, constitute the sediment or battery "mud" in the bottom of the tank. Excessive overcharge, in ampere hours, especially at high rates, is to be avoided for the above reasons. A limited amount of overcharge, however, is necessary to keep the plates in good condition. Also a certain amount of sediment is normally to be expected, but proper operation will

insure that it is a minimum amount. All of these statements hold true whether the plates be of the Planté or of the pasted type. The pasted plates are characterized by having relatively large masses of active materials, with a small amount of lead grid surface, while with Planté plates there are relatively small masses of active material with lead underlying them, the developed area of the lead being great.

In the action of the batteries with the Planté plates there is a normal slow corrosion of this lead, forming new active material. The capacity of these plates may diminish, remain normal, or even increase, as long as there is reserve lead in the plates, accord-

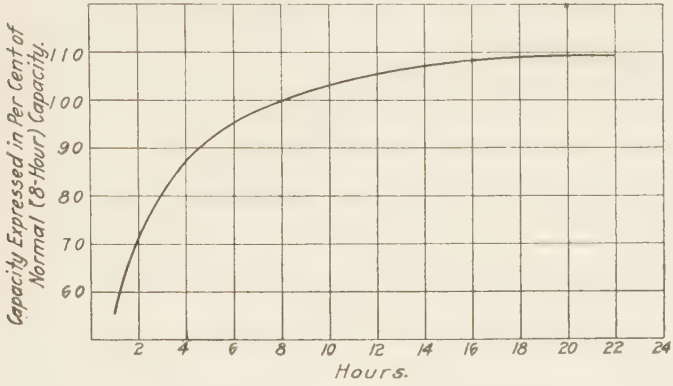


Fig. 65—Percentage of Variation of Capacity With Varying Rates of Discharge.

ing as this reserve lead is corroded and converted into active material at a lower, the same, or at a greater rate than that at which the original active material sheds off.

As the active material on a pasted plate sheds off during its life, the capacity diminishes as the plates age, because there is no reserve lead to be converted into new active material to take the place of that which is shed.

Reason for the Growth of Plates.—As the lead sulphate and lead peroxide that is formed cohere with the lead and occupy a greater volume than the original lead, there is a tendency for the plate to stretch or grow, principally in the length direction of the ribs.

Unequal corrosion on the two sides of the plate will result

in an unequal growth of the two sides and cause the plate to warp or buckle. The conditions at the negative plate are such that normally there is no such corrosion; therefore no growth or buckling. With these facts in view it is plainly necessary that batteries should be so operated that the rate of corrosion of the underlying lead of the positive plates will be kept within bounds.

New active material should be formed at about the same rate as the old active material falls off in the form of sediment.

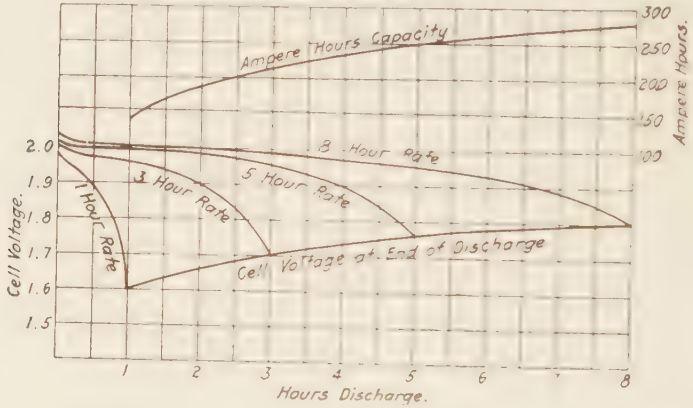


FIG. 66—Variation of Capacity With Various Discharge Rates, Showing Corresponding Terminal Voltage.

The rate of corrosion of the lead underlying the positive active material may be high, under certain conditions, which are:

1. With discharged positives, the remaining lead peroxide automatically discharges into the underlying lead. A battery should not, therefore, be allowed to stand any longer than necessary in a discharged condition.
2. With low rates of charge, the chemical reactions previously described are departed from on the positives, and the current instead of wholly converting the lead sulphate, previously formed on discharge, into lead peroxide, accomplishes this only partially and in addition corrodes some of the underlying reserve lead to lead sulphate.
3. Violent corrosion of positive plates may occur if traces of acids or acid forming substances other than sulphuric acid are allowed to get into the electrolyte.

As mentioned (2) low charging rates—rates less than eight

hour rates—are to be avoided, especially if the battery is in a discharged condition. Either of the effects mentioned in (1) and (2) are usually relatively slow, but may under certain conditions be greatly accelerated, for example, high temperature and weak electrolyte.

Ampere-Hour Capacity of a Lead Battery.—The rated capacity of a battery is the normal discharge rate in amperes, times eight hours, and the battery is considered completely discharged when the potential difference at the terminals falls to 1.8 volts per cell, with the battery discharging at normal rate and the normal temperature.

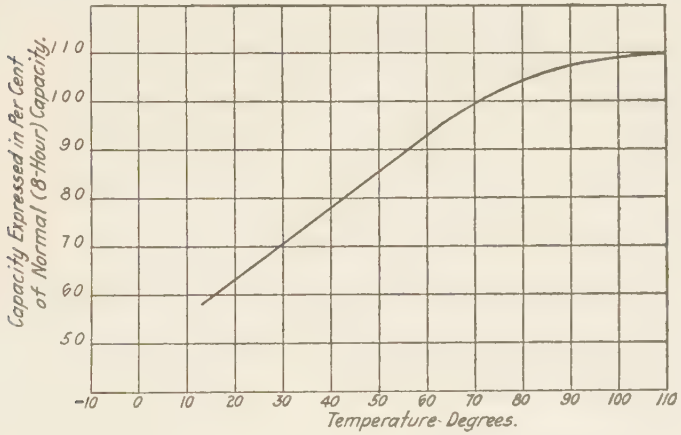


FIG. 67—Variation of Capacity With Variation of Temperature.

The capacity varies with the rate of discharge, being less at high than at low rates, principally on account of the less time for acid diffusion. Fig. 65 gives a curve showing the variation of capacity with various rates of discharge expressed in per cent of the eight hour capacity.

The variation of capacity at various discharge rates and the corresponding terminal voltage for each rate is shown in Fig. 66.

The capacity of a battery also varies with the variation of the temperature above or below normal, which is 70 degrees F. Fig. 67 shows the relation between these two factors.

Method of Maintaining the Capacity.—The maintenance of the voltage, and consequently the capacity of the battery, depends upon both the positive and the negative plates. Therefore, if the

plates of either positive or negative groups be lacking in capacity, either on account of being deficient in active material, or on account of being only partially charged, or for any other reason, the capacity of the battery as a whole is only approximately equal to that of the group having the least capacity. It is therefore necessary that both positive and negative plates be fully charged and that they both have a sufficient quantity of active material.

The voltage reading of the battery is not an absolute indication of the condition of the plates and to determine the condition and the capacity of the positive and negative plates it is necessary to test each plate independently.

This test is made by immersing a piece of metal, known as cadmium, in the electrolyte, while the battery is on discharge and observing the voltage between it and the positive and negative groups. The cadmium test will be described in detail in a later chapter.

CHAPTER VIII

TRAIN LIGHTING STORAGE BATTERIES—II

There are many designs of storage batteries used in car lighting service, some of them are designed especially for this service. These include the Edison, Exide, and Putnam batteries which are described in this chapter.

The Edison Storage Battery differs widely from all other types in theory and characteristics. It has an alkaline instead of an acid electrolyte, and the active materials are nickel oxide and iron instead of lead peroxide and spongy lead. The Edison storage battery for railway cars consists of a number of cells each of which is a unit consisting of the following main parts:

1. Containing vessel with cover.
2. Positive and negative groups of plates.
3. Electrolyte.
4. Insulators.
5. Connectors.

These parts are shown in Fig. 69. For train lighting there are six types. These are as follows:

Type A-4-H, rated capacity 150 ampere hours.
Type A-5-H, rated capacity 187.5 ampere hours.
Type A-6-H, rated capacity 225 ampere hours.
Type A-8-H, rated capacity 300 ampere hours.
Type A-10-H, rated capacity 375 ampere hours.
Type A-12-H, rated capacity 450 ampere hours.

The letter "A" in each type represents the size of the plates used; the number represents the number of positive plates in each cell; the letter "H" indicates "High Type," as for train lighting the cells are assembled in higher containing vessels than for other use, giving about three inches additional space for solution. This

feature permits of working batteries for longer periods without adding water.

Containing Vessel.—The containing vessel, Fig. 69, is made

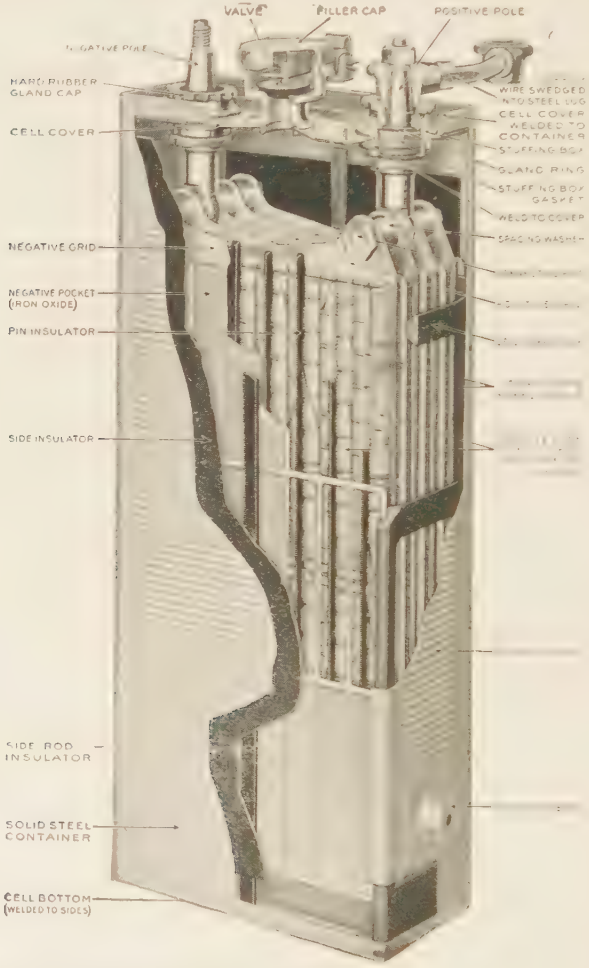


Fig. 69—The Edison Alkaline Storage Cell, Showing the Various Parts.

of cold rolled, heavily nickeled, sheet steel, all seams being welded by the autogenous process, "oxygen-acetylene flame." The walls of the container are corrugated so as to give maximum strength with minimum weight. Bosses are welded on the sides to hold

the cell in the tray and to keep the cells separated when they are connected up for service. The containing vessel cover is made of nickel sheet steel and is welded on, after the elements have been

Fig. 70.

Fig. 71.

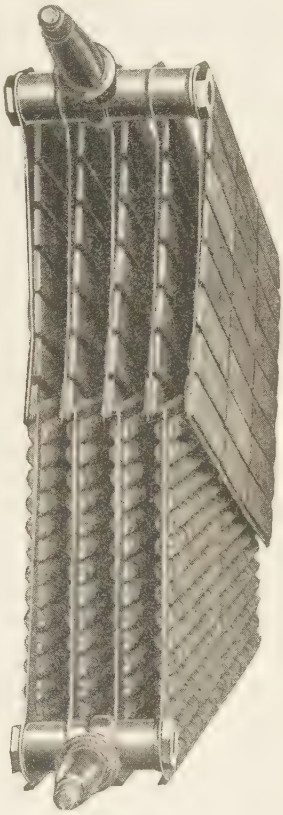


Fig. 72.

Fig. 70—Type "A" Positive Tube Loaded With Nickel Hydrate, Ready to Place in Positive Grid—8 Seamless Rings Encircling the Tube.
Fig. 71—Negative Pocket, Type "A" Loaded With Iron Oxide, 3 in. long, ½ in. wide, ⅛ in. thick.
Fig. 72—Method of Intermeshing the Positive and Negative Plates in Assembling a Cell for Placing in the Container.

placed in the containing vessel. The battery terminal poles pass through fittings in the containing vessel cover. These fittings are provided with soft rubber washers, and with rings and gland caps for expanding these rubber washers to form a gas tight and

liquid tight packing between the top of the container and the poles. The cover supports a combination filler cap and valve. The filler cap is operated by a spring which holds it wide open for filling or closed for operating, as desired. The valve is suspended from the under side of the filler cap and is so arranged that, as the gas pressure in the cell rises sufficiently to raise it, the escaping gas flows by and out under the filler cap. When the gas has escaped, the valve closes preventing any impurities from getting into the cell.

Groups of Plates.—The positive plates are mounted on a steel connector rod with steel spacing washers and steel terminal post

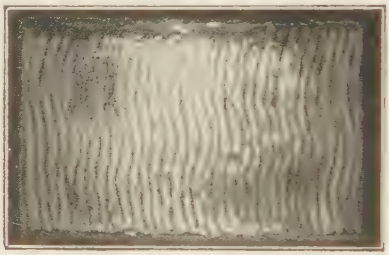


FIG. 73—Magnified Section of ¼-in. Tube. Light Layers Show Nickel Hydrate. Dark Vertical Lines Show Nickel Flake.

as shown in Fig. 69. The negative plates are also mounted on a steel connector rod with spacing washer and steel terminal post. The positive and negative groups thus formed are intermeshed as shown in Fig. 72; being kept separate electrically by suitable rubber insulation, and are then ready to be slipped into the steel container.

Positive Plates. The active material of the positive plate is nickel hydrate, which is packed in thin layers under heavy pressure in perforated steel tubes, as shown in Fig. 73, which is an enlarged cross sectional view of a portion of one of the tubes. Between the layers of nickel hydrate are still thinner layers of pure nickel which appear as dark lines in the illustration. These metallic layers are made up of small flakes of nickel, each flake being about 1/16″ square and much thinner than very thin tissue paper.

During charge and discharge of the battery the passage of

electric current alternately oxidizes and reduces the nickel hydrate. The metallic nickel acts as a conductor, forming a path of low resistance to all parts of the active layers of hydrate. After the steel tubes are loaded they are strengthened by a number of encircling seamless steel rings, as shown in Fig. 70. Then they are mounted in a steel grid or frame; the result is a strong positive plate.

The type "A" positive plates are used in all train lighting cells. These plates are composed of thirty perforated nickel steel tubes

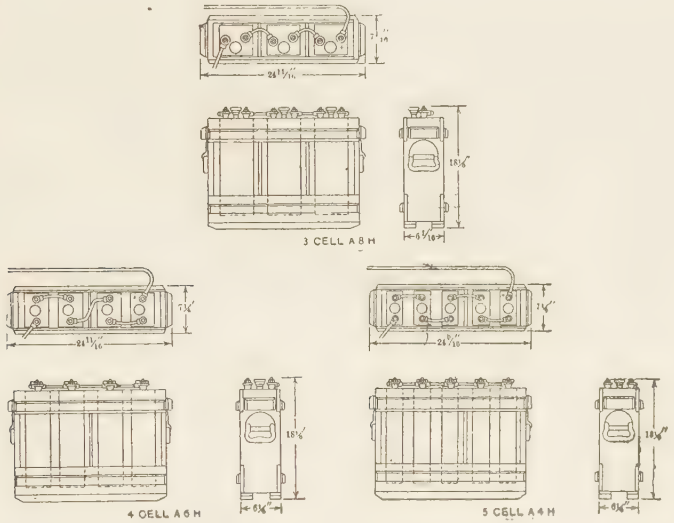


Fig. 74—Assembly of Edison Cells in Trays.

arranged in two rows of fifteen each. Each type "A" positive tube is ¼ in. in diameter, 4½ in. long and contains 700 alternate layers of nickel oxide and pure metallic nickel.

Negative Plates.—The negative plate consists of a steel grid, which supports a number of flat, perforated steel containers or pockets. The active material is iron oxide, which is held within the pockets. The pockets after being placed in the openings of the grid are subjected to hydraulic pressure which forces them into permanent contact with the grid. The passage of current during the operation of the battery causes the active material of

the negative plate to be alternately reduced and oxidized as the battery is charging or discharging. The complete negative plate contains 24 pockets, arranged in three rows of eight pockets each. Each pocket is ⅛ in. thick, ½ in. wide, and 3 in. long.

Electrolyte.—The electrolyte of an Edison battery is an alkaline and not an acid solution such as is used in a lead cell. An acid solution could not be used in an Edison cell because acid would act upon the nickel and steel electrodes. On the other hand, the alkaline solution preserves the steel and nickel and this in itself is a distinctive feature of the Edison cell.

The original electrolyte of the Edison cell is a 21 per cent solution of potassium hydrate—caustic potash—to which is added a small amount of lithium hydrate. This solution has a normal specific gravity of 1.210 at 60 deg. F. which does not change over a long period. The specific gravity of a liquid is the weight of that liquid divided by the weight of an equal volume of water. During the war, caustic potash was not obtainable and caustic soda was substituted, which has a normal specific gravity of 1.175 at 60 deg. F.

Separators-Insulation. The alternate positive and negative plates are insulated from each other by vertical hard rubber pins or rods, equidistantly placed. Moulded hard rubber "ladders" secure the plates at their edges and insulate the whole group from the containing can. A sheet of hard rubber is placed between the end negatives and the container. A moulded hard rubber "stool" forms the bottom support for the plates.

Trays.—The cells are mounted in wooden trays as shown in Fig. 74, being supported either by a steel cradle and hold-down straps or by rubber buttons imbedded in the tray slats. In the latter case the cells are provided with steel bosses which fit into the rubber buttons in the tray slats. These supports maintain the cells in position even when subjected to violent concussion. The trays are designed to contain any desired number of cells to suit different conditions. In most cases the A-8-H battery is assembled three cells to a tray while the A-6-H is assembled four cells to a tray and the A-4-H five cells to a tray. These assemblies are shown in Fig. 74.

Connectors.—The individual cells in the tray are connected together positive to negative by means of copper connecting links.

The end cells in adjacent trays are connected together positive to negative by means of insulated copper wire jumpers. The links and jumpers are provided with steel terminal lugs which are bored, reamed, and ground to fit the tapered top of the terminal posts. The terminal lugs are brought into intimate contact with

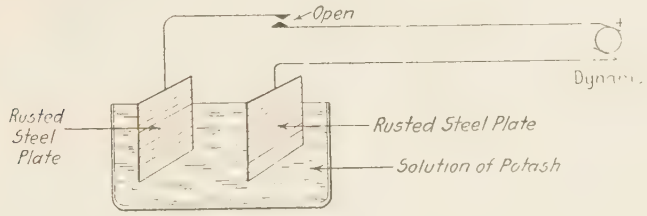


FIG. 75—Two Rusted Steel Plates Immersed in Solution of Potash and Connected by Two Wires to Dynamo.

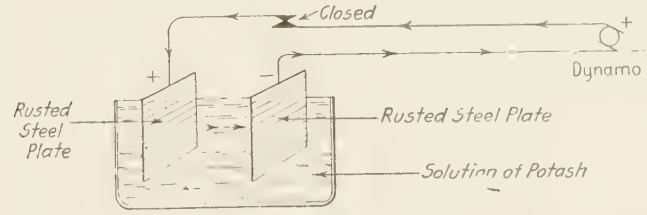


FIG. 76—Current Flows from Dynamo Through Solution, from One Plate to the Other and Back to the Dynamo as Shown by the Arrows.

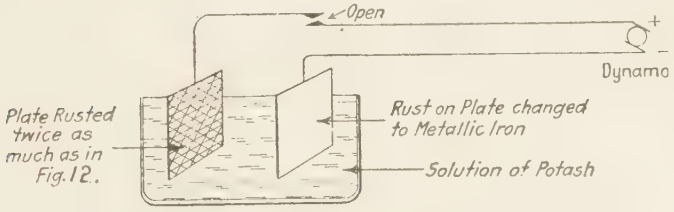


FIG. 77—Result of Charging as Shown in Fig. 76.

the terminal posts by tightening the nuts on top of the terminal posts.

Theory.—The Edison theory is totally different from that of all other storage batteries based upon either the Planté or the Faure theory. These latter use lead peroxide or spongy lead in an acid electrolyte, while the Edison battery employs nickel hydrate for

the positive active material, iron oxide for the negative active material, and an alkaline electrolyte.

A few points that lead up to the perfection of the Edison battery may be interesting and should enable the reader to grasp the theory more quickly.

If two pieces of very thin bright steel were placed out of doors for a few weeks they would rust. This means that the oxygen in the air has acted on the outer layer of the metal and formed an oxide commonly known as rust. Next place these two pieces

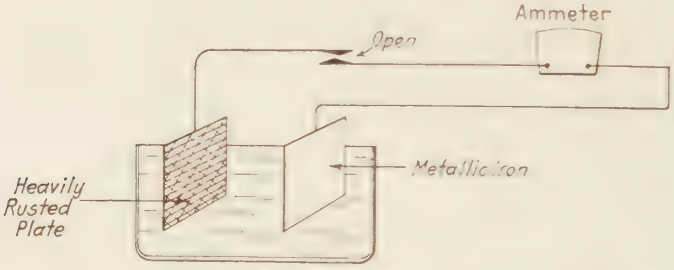


FIG. 78—Plates Disconnected From Dynamo and Connected to Ammeter.

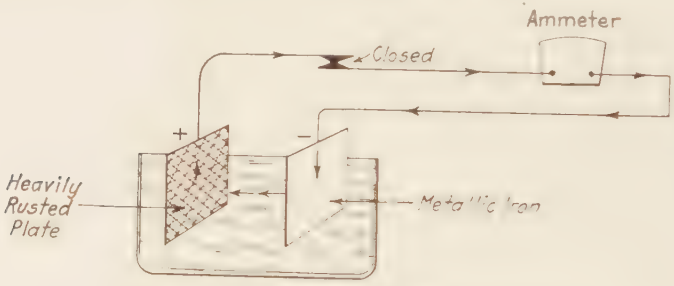


FIG. 79—Current Flows as Shown by Arrows.

of steel in a solution of potash and water, and connect them by wires to a small dynamo, as shown in Fig. 75. The electricity, in flowing from the dynamo through the solution, from one of the plates to the other and back to the dynamo as shown in Fig. 76, changes the rust to metallic iron on one of the plates, but causes the other plate to become rusted twice as much as before, see Fig. 77.

Now disconnect the plates from the dynamo and connect them, by means of pieces of wire to an ammeter, as shown in Fig. 78.

Instantly, the excess of oxygen in the rust on the plate commences to pass back to the bright plate and by so doing causes the electricity to be generated, Fig. 79.

We have now charged and discharged a primitive storage battery. Instead of two thin rusted steel plates, let us mount, say, one hundred such plates, equidistantly spaced on one rod, and one hundred more on another rod. Now interpose the two groups so that the plates of one group will not touch those of the other and immerse them in a solution of potash. When connected to the dynamo the electricity will flow from one group, through the solution, to the other group, converting the oxide of one group to metallic iron and increasing the amount of oxide on the other group. We shall be able to get much more electricity from the battery thus formed, because of the greater plate surface exposed.

Thus it has been determined that large surface is necessary. Next place a quantity of fine particles of iron rust in two perforated flat steel pockets, and after putting these pockets into potash solution pass electricity from one to the other, through the solution as before. All the iron rust in one pocket will be changed to metallic iron, because the oxygen will have passed over to the iron rust in the other pocket, causing this material to possess twice as much oxygen as before.

Connect the two pockets to an ammeter and it will be found that much more electricity is flowing than before, although the two pockets take up much less space than the two hundred steel plates. The reason of this is, the small particles present a very great combined surface to the solution.

Suppose after having made a great number of experiments you put some iron rust or iron oxide into perforated steel pockets, and mount a number of these pockets in a steel grid or support to form one plate, and place nickel hydrate—a green powder—in perforated steel receptacles and mount them on another grid to form another plate, then immerse the whole in a solution of potash, you will have arrived at the point Edison reached when he invented the Edison storage battery.

Chemical Action of an Edison Cell.—As it is chemical energy that is stored in the battery and not electricity, it is necessary when explaining the action that takes place in the battery to include chemical symbols and equations. Therefore an ex-

planation of a few terms may help those who have not studied chemistry.

The symbols for the elements which will be used are as follows:

Elements	Symbols
Hydrogen	H
Oxygen	O
Potassium	K
Nickel	Ni
Iron	Fe

The elements are combined into the following:

The formula for nickel oxide is NiO_2 meaning that nickel and oxygen are combined to form nickel oxide. The formula for water is H_2O meaning that hydrogen and oxygen are combined to form water. Iron oxide is Fe_3O_4 indicating that iron and oxygen are combined to form iron oxide, and potassium hydrate is KOH signifying a combination of potassium, oxygen and hydrogen.

The fundamental principle of the Edison storage battery is the oxidation and reduction of metals in an electrolyte which neither combines with nor dissolves either the metals or their oxide. Also, an electrolyte which, notwithstanding its decomposition by the action of the battery, is immediately reformed in equal quantity and is therefore a practically constant element without change of density or conductivity over long periods of time. Therefore, only a small quantity of such electrolyte is necessary, permitting a very close proximity of the plates. Furthermore, it is unnecessary to take hydrometer readings until about three hundred cycles of charge and discharge have been made; this is simply to determine when it is necessary to empty out the old solution and put in new. The active material of the plates being insoluble in the electrolyte no chemical deterioration takes place therefrom.

The chemical reactions in charging the Edison storage battery are (1) the oxidation from a lower to a higher oxide of nickel in the positive plate and (2) the reduction from ferrous oxide to metallic iron in the negative plate. The oxidation and reduction are performed by the oxygen and hydrogen set free at the respective poles by the electrolytic decomposition of water during the charge. The charging of the positive plates is therefore simply a process of increasing the proportion of oxygen to nickel. The

proportion of nickel to oxygen in the various oxides of nickel are as follows:

	Atomic Proportions		By Weight	
	Ni	O	Ni	O
NiO	1	1	1	.273
Ni_3O_4	1	1.33	1	.364
Ni_2O_3	1	1.5	1	.409
NiO_2	1	2	2	.545

The relative amounts of oxygen necessary to oxidize nickelous oxide, or NiO, which is the oxide corresponding to the green nickel hydrate used in making the battery, to the various oxides are given in the three reactions.

(1.) $6\,NiO + 2\,O = 2\,Ni_3O_4$

(2.) $6\,NiO + 3\,O = 3\,Ni_2O_3$

(3.) $6\,NiO + 6\,O = 6\,Ni\,O_2$

The NiO_2 is capable of reacting with NiO according to the reaction $NiO_2 + NiO = Ni_2O_3$.

Ni_3O_4 is considered as a combination of NiO plus Ni_2O_3. From a chemical standpoint a charged condition of the cell would, therefore, be represented in the positive plate by an atomic ratio of nickel to oxygen of at least 1 : 1.5 (or Ni_2O_3), depending on the charge. A discharged condition would be represented by a ratio of 1 : 1.33 (Ni_3O_4) or lower, depending on the discharge. The discharge of a cell is simply the reversal of the above reactions, the hydrogen reducing the higher oxides of nickel to lower oxides and the oxygen oxidizing the iron to ferrous oxide.

A Complete Cycle in a Simple Form.—The following explanation of the chemical action may be more easily understood by those who are not familiar with chemistry. Starting with iron oxide in the negative, green nickel hydrate in the positive, and potassium hydrate in the solution, the first charging of the cell reduces the iron oxide to metallic iron while converting the nickel hydrate to a very high oxide, black in color.

On discharge the metallic iron goes back to iron oxide and the high nickel oxide goes to a lower oxide, but not to its original form of green hydrate.

On every cycle thereafter the negative charges to metallic iron and discharges to iron oxide, while the positive charges to a high nickel oxide. The current passing in the direction of charge or discharge, decomposes the potassium hydrate of the electrolyte,

and the oxidation and reduction at the electrodes are brought about by the action of its elements. An amount of potassium hydrate equal to that decomposed is always reformed at one of the electrodes by a secondary chemical reaction and the consequence is, there is none of it lost and its density remains practically constant.

The eventual result of charging, therefore, is a transference of oxygen from the iron to the nickel electrodes, and that of dis-

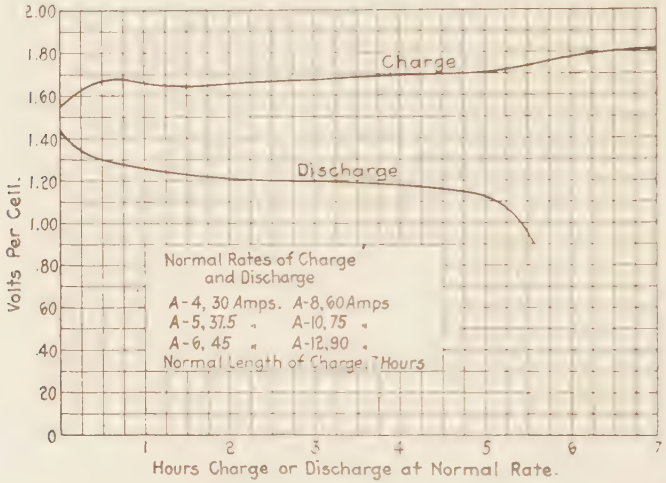


FIG. 80—Normal Charge and Discharge Voltage Curves of Type "A" Cell.

charging is a transference back again. This is why the Edison is sometimes called the oxygen lift cell.

The above action on discharge may be approximately represented by the following equations:

Positive—8 K + 6 NiO_2 equals 2 Ni_3O_4 plus 4 K_2O.

Negative—8 OH plus 3 Fe equals Fe_3O_4 plus 4 H_2O.

The reverse reactions take place on charge. The iron and nickel compounds are probably hydrated but are here treated as oxides for the sake of simplicity. It will be noticed that the same amount of KOH is decomposed according to the left hand members of these equations as is reformed simultaneously as shown on the right. For this reason the chemical composition or specific gravity

of the solution does not change appreciably throughout the cycle of charge and discharge.

Capacity and Charging Rates. The following table shows the capacity, normal discharging and charging rates, etc., for the various types:

Type	A-4-H	A-5-H	A-6-H	A-8-H	A-10-H	A-12-H
Capacity, amp. hrs.	150	187.5	225	300	375	450
No. of positive plates	4	5	6	8	10	12
No. of negative plates	5	6	7	9	11	13
Charging rate, 7 hrs., amps.	30	37.5	45	60	75	90
Discharge rate, 5 hrs., amps.	30	37.5	45	60	75	90
Discharge rate, 8 hrs., amps.	18.75	23.4	28	37.5	47	56.25
Average discharge voltage per cell	1.24	1.24	1.24	1.24	1.24	1.24
Average discharge voltage 25 cells	31	31	31	31	31	31
Average discharge voltage 50 cells	62	62	62	62	62	62
Weight of single cell, lbs.	16.3	19.4	22.6	30.7	38.3	46.9
Weight of 25 cell battery, lbs.	485	563	643	863	1,150	1,350
Weight of 50 cell battery, lbs.	970	1,125	1,285	1,725	2,300	2,700
Height of solution above plates	3″	3″	3″	2¾″	2¾″	2¾″
Cell container dimensions, length	2.60″	3.23″	3.81″	5.06″	6.19″	7.37″
Cell container dimensions, width	5.12″	5.12″	5.12″	5.25″	5.50″	5.50″
Cell container dimensions, height	15.00″	15.00″	15.00″	15.25″	15.25″	15.38″

The range of voltage during a normal seven hour charge is from about 1.6 per cell minimum to 1.8 maximum.

The range of voltage during a normal five hour discharge is from about 1.4 per cell maximum to 1 volt per cell minimum.

Fig. 80 shows normal charge and discharge voltage curves of a type "A" train lighting Edison cell.

The "Exide" Storage Battery—Fig. 81—essentially different in material, design and construction from what is generally termed the lead battery. The component parts are the Manchester positive plate, the Box negative plate, and the wood separators.

The Manchester positive plate—Fig. 82—has a grid of cast lead-antimony alloy which resists the forming action of the electric current during charge and discharge. It cannot be converted into lead-peroxide and is, therefore, permanent throughout the entire life of the plate. Being of very rigid construction it resists the mechanical strains which occur and retains its original shape without growth or buckling. The grid provides the necessary support for the active material and also a conducting metal for carrying the current to and from all parts of the plate during charge and discharge. It has circular openings, slightly tapered toward the center, into which are forced by hydraulic pressure buttons of soft lead—Fig. 84—that constitute the active portion of the plate. These buttons are formed of strips of pure lead corrugated transversely and rolled into a spiral. After being

forced into the grid, they are subjected to an electro-chemical forming action which expands the buttons and locks them into place. Any tendency to "grow" merely locks them tighter in the grid without distorting the latter and thus the entire electrolytic action is confined to the buttons.

The negative plate Fig. 83 is the box type grid, and consists of horizontal and vertical ribs spaced about one inch apart forming pockets closed by perforated sheet lead. The grid and the

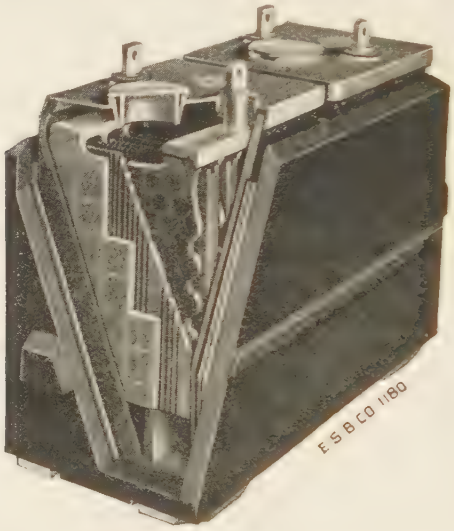


FIG. 81—Two-Cell "Exide" Storage Battery Showing Interior Construction.

active material are not necessarily of the same composition, but each is designed of material suited for the functions that it is to perform. The grid remains rigid and inactive, whereas the active material is exceedingly porous and spongy. This results in a permanent negative plate whose capacity is well maintained.

The grids are assembled into positive and negative groups by lead-burning them to the plate strap and terminal post. This plate-strap is designed to give maximum rigidity at the junction with the plate lug, and an apron is provided at the back to hold the separators in place. Great care is exercised in grouping the grids to avoid the possibility of loose plates, due to shock and vibration incident to car lighting service. The work is done in accurate gages, to insure each plate resting on the plate support

in the bottom of the jar and at the same time bringing the post in proper alignment with the cover openings.

Wood separators—Fig. 85—of heavy section, grooved on both sides, are used between the plates. Wide ribs on either vertical

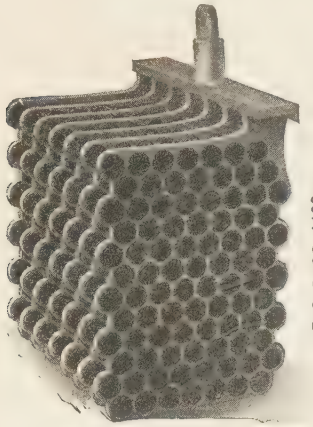


FIG. 82—Manchester Positive Group.

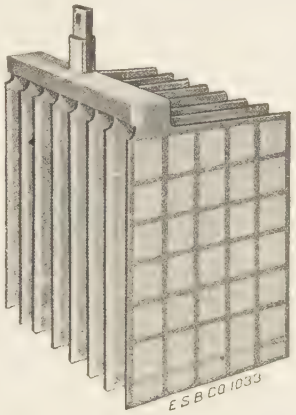


FIG. 83—Box Negative Group.

edge and at two intermediate points where the separator rests on the plate supports, effectively separates the plates throughout their entire surface and at the same time permits ample and rapid diffusion of the acid. Short circuits and dead cells are avoided.

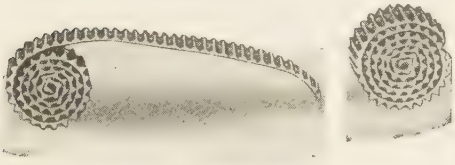


FIG. 84—Manchester Button.

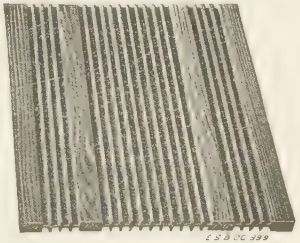


FIG. 85—Wood Separator.

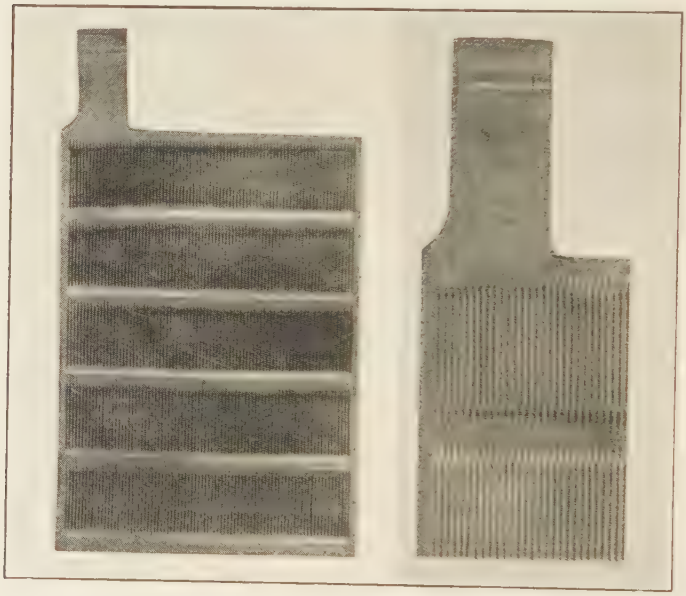
Thus buckling and swelling are avoided, and there is no pressure from inside to strain the walls of the container.

The Putnam Storage Battery.—A new type of lead storage battery—known as the "Putnam"—has recently been devised for train lighting purposes. Excepting such sets as are provided with a special filling arrangement for flushing the cells without remov-

ing the crates from their positions in the battery compartment under the car, the general appearance of the Putnam battery is similar to other types of lead batteries having two cells in a crate.

Plate Construction.—The plates are of the "Planté" type. Both the positive and negative elements are made of several leaves, one of which is shown in Fig. 86. Each leaf is made from a sheet of chemically pure lead, milled so that it consists of several groups of parallel cylindrical pieces held by rectangular cross members.

Six of these leaves are used to make one positive element;



(a) (b)

FIG. 86—(a) One of the Leaves or Units Which Make Up an Element. (b) Section of One of the Leaves Showing Wire Construction.

eight are used to make an inside negative element and five for each of the two outside negative elements. The four outer edges of the leaves making the negative group are burned together before the element is connected to the strap. In the case of the positive element, however, the leaves are attached to a lead bar and burned together along the upper edge only so that each leaf is free to expand or "grow" both laterally and vertically. Instead of using separators, each positive element is placed in a reinforced

rubber envelope as shown in Fig. 87. The envelope also acts as a suspension for the element. It is made larger than the plate to allow for the normal growth of the latter during formation.

The advantages claimed for this type of plate construction are: that the cylindrical rod construction eliminates entirely the tendency of active material to separate from the base lead; buckling of plates is eliminated; and the largest possible amount

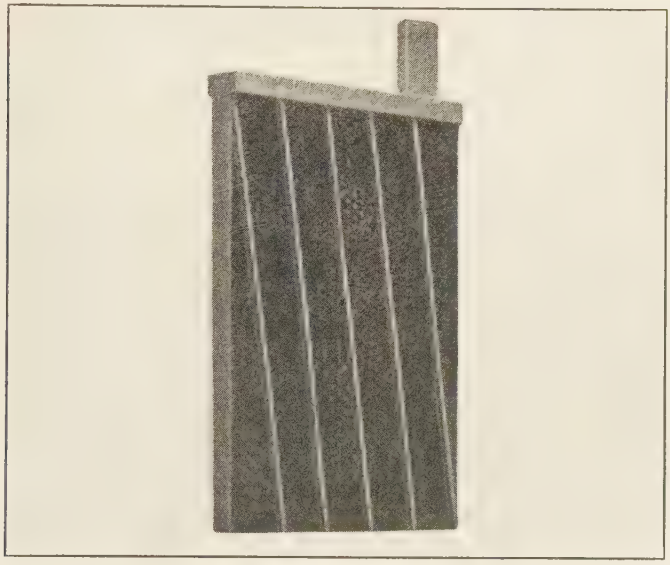


Fig. 87—A Positive Element Complete in Its Reinforced Rubber Container.

of reserve lead is retained after the original formation, with a minimum total weight of plate.

Assembly.—The "Putnam" battery is assembled in two-cell units and can be supplied either with or without the special filling device as shown in Fig. 88. Either rubber jars or lead tanks are used as containers for the plate groups and the two containers in turn are placed in a solid wooden battery box. Lead-Antimony covers are used for both rubber and lead jars. When provided with the special filling device, only a small vent hole is left in the cover as the battery cells are flushed through the two filler openings shown at the left in Fig. 88. Each filler opening is covered by a threaded hard rubber plug and is connected to a

tank or jar through a piece of lead tubing. As both openings are mounted on the front of the battery box, the splashing or spilling of acid over the tops of the batteries, when flushing or taking hydrometer readings, is minimized. The small opening or vent, for the escape of gas, in the cell covers is one inch higher than the filler openings in front, thus making it practically impossible to flood the cell when filling.

Connections.—The risers from the groups are cylindrical and are fitted in the covers through soft rubber bushings. The

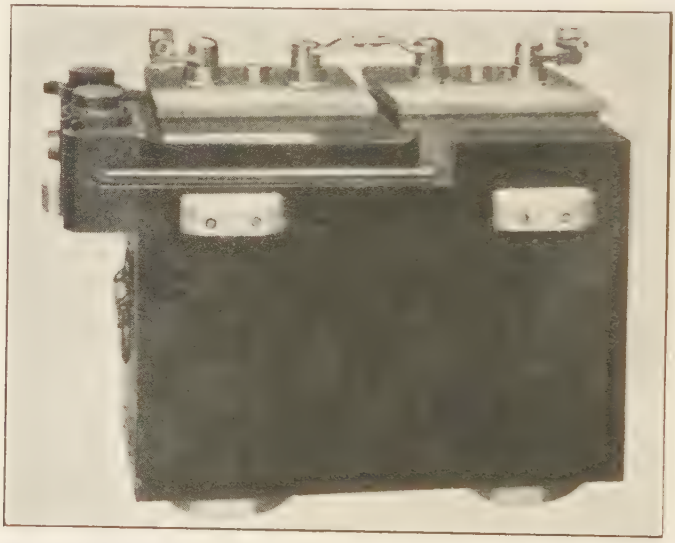


FIG. 88—"Putnam" Two-Cell, 300 Ampere-Hour Unit With Front Filler.

terminals are burned on the risers at the top only so that when heat is applied to the top of a terminal it can be pulled off.

The bolts and nuts used for making the connections to the terminals are made of a special alloy. This alloy, in appearance, is similar to lead, but is much harder. It has such properties that it will take a good thread on which the nut will not bind; it has about half the tensile strength of brass and is non-corrosive. An amalgam washer is used between battery terminal and the connector terminal. This washer prevents a film of insulating sulphate being formed at the connections; such a film would cause the introduction of considerable resistance in the battery circuit.

CHAPTER IX

THE AMPERE-HOUR METER

The ampere-hour meter, Fig. 89, is an instrument for measuring ampere-hours—current in amperes multiplied by time in hours equals ampere-hours. The ampere-hour is the unit in which the capacity of a storage battery is measured and therefore the ampere-hour meter is a very useful instrument in car lighting service. It indicates the condition of a battery with respect to state of charge; that is to say, it will indicate that a battery is 20, 30 or 40 per cent charged, and therefore will give a certain percentage of a full discharge. This, however, is indicated in ampere-hours instead of percentage, although the percentage basis is a valuable aid in figuring battery efficiency.

Storage Battery Efficiency.—It is a well-known fact that storage batteries are not one hundred per cent efficient. They will not deliver an amount of current equal to the amount used in the previous charge. For example, the normal discharge rate of a certain lead cell is eight hours at 37.5 amperes, or a total of 8×37.5 or 300 ampere-hours. The normal charging rate of this same cell will be 8 hours at 45 amperes or a total of 8×45 or 360 ampere-hours. Note that it required 360 ampere-hours to charge the battery, which, in turn, is capable of delivering only 300 ampere-hours. The efficiency in this case will be

$$\frac{300 \text{ of } 100\% \text{ or } 83.3\%}{360}$$

Another example is a type A-8-H Edison cell having a normal capacity of 300 ampere-hours. The normal discharge rate for this cell is 5 hours at 60 amperes or 300 ampere-hours, and the normal charging rate is 7 hours at 60 amperes or 420 ampere-hours. Note that in this case the battery requires a 420 ampere-

hour charge and delivers only 300 ampere-hours on discharge. The efficiency of this cell is

$$\frac{300}{420} \text{ of } 100\% \text{ or } 71.4\%$$

It must be remembered that these efficiencies were figured on a normal basis and that the normal efficiency of a battery is

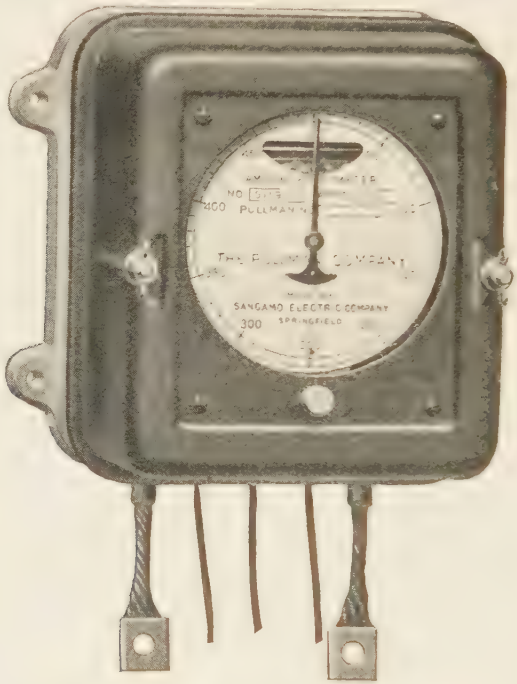


FIG. 89—The Sangamo Ampere-Hour Meter.

affected by a number of factors, one of which is the rate at which the battery is charged and discharged. For instance, one car will have a total discharge lamp load of only eight amperes while another will have a total discharge of 35 amperes; both cars equipped with the same size and type of battery. Consequently the efficiency of the same battery will vary on different classes of cars.

The normal efficiency of a battery is also affected by the strength of the electrolyte, condition of the plates, and the nature of the charge and discharge. It would not be reasonable to expect a battery four years old to have the same capacity as a new

one. Also, a battery neglected and abused, such as neglected flushing periods, or standing for long periods in a discharged condition, would not have the same efficiency as one of the same age that had received good care.

The nature of charge and discharge is variable. Compare two similar cars, one operating in an express train with a three-hour steady run between station stops, and the other operating in a local train with a ten minute run between stations. The battery on the car operating in the express train will receive a continuous three hour charge, while the battery of the car in the local train receives a ten minute charge and then a two minute discharge, then another ten minute charge and two minute discharge and so on, repeated again and again until the battery receives a charge equal in ampere-hours to the one in the express train. At the end of each run the ampere-hour meter on each car will indicate the batteries in the same condition as to their state of charge, but as the charge in each case was of a different nature, they will not have the same efficiency. That is to say, the steady charge has a higher efficiency than the interrupted charge or vice versa. Taking all these characteristics into consideration, one can easily see that it is not a small matter to determine upon the arrival of a car at a railroad terminal the condition of the battery with respect to its state of charge.

The Sangamo Ampere-Hour Meter—most widely used—however, has been designed, with the addition of new devices, in an effort to compensate for some of the conditions that affect battery efficiency and today this meter is a very essential part of nearly every car lighting equipment.

Types of Ampere-Hour Meters.—Ampere-hour meters of various types have been used abroad in the sale of electricity, on consumers' circuits for many years, but this practice has not been used in the United States and Canada. Various types have been devised but only four have been developed so as to obtain any practical recognition, namely:

1. Mercury-motor meter.
2. Commutator or wound armature type with permanent magnet.
3. Oscillating type meter.
4. Electrolytic type.

The first type is generally used for car lighting. This type has

212833

proved its superiority over the others through a period of more than twenty five years in England and about ten years in this country. The second and third types are not used to any appreciable extent in storage battery operation. The fourth type, which depends upon the electrolysis of water or salts of mercury, though still used to a considerable extent, is not suitable for car lighting storage battery work on account of its being non-reversible.

Principle of Mercury-Motor Meter.—The mercury-motor type of ampere-hour meter consists essentially of a metallic disc armature submerged in mercury, with suitable contacts embedded in the chamber containing this armature, so that current may be led through the mercury bath and the armature therein, with proper relation to a magnetic field established by a permanent magnet with its poles in proximity to the mercury bath and armature. The current is led into and out from the armature at opposite ends of a diameter of the chamber, and in passing across is subjected to the action of the magnetic fields of opposite polarities, on opposite sides of the center, so that a continual torque is obtained.

The torque exerted on the moving element is proportional to the product of the magnetism and the current through the armature. The magnetic field, being supplied by a permanent magnet, is constant, so that the torque in this meter is directly proportional to the current through it.

On the same shaft with the armature element there is fastened a disc rotating in the field of another permanent magnet which operates as a generator, and the torque required to turn this disc is directly proportional to the speed. Therefore, the speed of the moving element, neglecting fluid and mechanical friction, is proportional to the torque, which in turn is proportional to the current. Therefore, the speed is a measure of the current and each revolution is equivalent to a definite and fixed amount of electricity.

With suitable gear train driven from the shaft carrying the disc armature, the dial attached to the gear train may be made to read in ampere-hours of electricity, that is the product of current and time.

This type of mercury-motor ampere-hour meter has many

advantages over the other types mentioned above, principally in durability of construction, ability to withstand most severe jarring and vibration without injury to the structure of the meter, simplicity of operation on shunts for large capacities, and adaptability to the various special features required for ampere-hour meters in service with storage batteries.

Construction of Sangamo Ampere-Hour Meter.—In the Sangamo mercury-motor ampere-hour meter the principles just described are embodied in the form of a copper disc armature, slotted to increase the rotative effect by guiding the current flow through the armature and between the contacts of the insulating

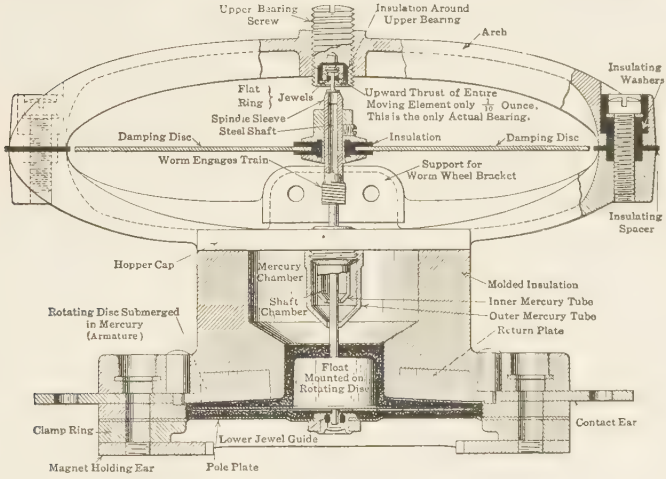


FIG. 90—Cross Section of Mercury Motor of Sangamo Two-Wire, Direct Current Ampere-Hour Meter, With Recording Mechanism, Field Magnets, and Damping Magnets Removed.

mercury chamber in which the armature is contained. As shown in the cross section, Fig. 90, the armature has a float which gives necessary buoyancy for the entire moving system, including the armature, shaft and damping disc above the mercury chamber. This damping disc is in turn acted upon by permanent magnets, separate from the main driving magnet, so that proper control and adjustment of main speed may be obtained. A large U-shaped permanent magnet surrounds the armature chamber, with its pole pieces at the bottom, the return magnet circuit for the flux set up

by this magnet being through a laminated steel ring in the upper part of the armature chamber above the disc.

At the lower end of the shaft a ring jewel guide is used, but as there is no pressure of the moving system downward, no end bearing is required. The shaft passes through a double tube arrangement by which spilling of mercury is effectually prevented when the meter is turned upside down or on its side. This is a considerable improvement over the former single tube device used in Sangamo meters for the same purpose.

At the top the shaft carries a sleeve with a worm driving the recording train; this sleeve also supports the aluminum damping disc. In the center of the cast iron arch above is carried the upper jewel bearing, consisting of a ring jewel to guide the shaft and an end jewel to receive the very light upward thrust of the entire moving system, amounting to about one-tenth ounce. The upper bearing is adjusted to give a very slight lift to the moving system so that the armature stands practically central in the mercury chamber.

With this construction there is practically no bearing friction on the jewels and any vibration or jar to which the meter is subjected—which in another construction might seriously damage the pivot and bearing jewels of the moving system—is effectually damped out by the dash pot action of the armature immersed in mercury. Sangamo ampere-hour meters may therefore be employed in the most severe train lighting service without danger or injury to any part of the motor element, the driving magnets, or the damping magnets. The following special features serve to adapt Sangamo ampere-hour meter to the requirements of actual service conditions.

Overcharge Feature.—Any battery whether of the lead or nickel-iron type will require, under the very best conditions, about ten per cent more electricity to be put in on a charge than can be taken out on the next discharge, and under many conditions, thirty per cent more is required. It may be fairly stated as an average condition, that an overcharge of from ten to thirty per cent will be required.

With a simple ampere-hour meter as described, and assuming that a battery is discharged through such meter, properly calibrated, true ampere-hours will be recorded. If on the next

charge the indicator of the meter were simply returned to the point from which it started, the battery would not be fully charged and the indicator would have to continue past the original point by ten to thirty per cent, depending upon the conditions, in order that the battery should be fully charged. This would make the use of the meter impracticable unless some means were devised to compensate for these variable conditions. In Sangamo ampere-hour meters this difficulty is overcome by the use of a variable resistor element, and differential shunt or a manual resetting device.

Variable Resistor Element.—The variable resistor element, generally used in Sangamo ampere-hour meters to compensate for

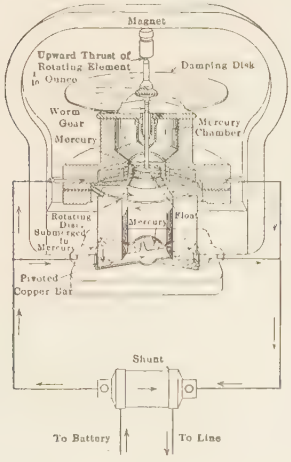


FIG. 91

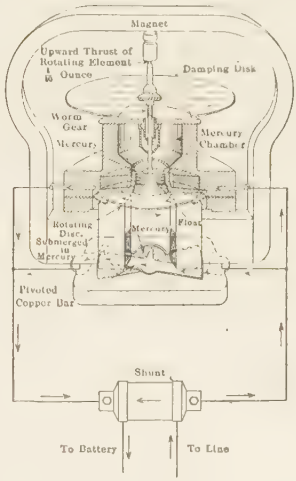


FIG. 92

FIG. 91—Diagram of Meter With New Type Resistor, Showing Position of Resistor Vane on Discharge. Arrows Show Direction of Current Flow.

FIG. 92—Diagram of Meter With Resistor, Showing Position of Vane on Charge.

overcharge, consists of a narrow copper bar immersed in a mercury filled chamber, similar to the armature chamber of the meter proper, except that the bar, instead of rotating, is limited to a certain angle of swing so that at one position it lies between contacts embedded at opposite ends of the chamber, while at the

other end of the swing it is away from the contacts; the path of current through the resistor lies largely through mercury of relatively high resistance instead of principally through the copper bar. By having this element in parallel with the main armature chamber or measuring element of a Sangamo ampere-hour meter, either with or without a shunt for large capacities, a different amount of current will pass through the measuring element for a given flow of current in the main circuit, depending upon whether the resistor bar is at the point of minimum or maximum resistance between contacts. By a simple adjustment, the angle of swing may be limited to any desired amount from zero, when no effect will be obtained, to the maximum, giving approximately thirty per cent overcharge. Therefore, by means of the resistor a most satisfactory and easily altered adjustment for overcharge is obtained.

The resistor bar swings automatically upon the reversal of current flow through the meter. This is due to the resistor element being located directly beneath the pole pieces of the driving magnet, so that the current passing through the resistor bar reacts with the leakage field from the pole pieces, causing the bar to swing to one extremity or the other within the chamber, according to the direction of current flow. Therefore, the bar will be at the point of maximum resistance as in Fig. 91 on discharge, while if current be reversed, as shown on the next succeeding charge, it will immediately swing to the point of minimum resistance between contacts as shown in Fig. 92, and will remain there as long as the current continues in the charge direction.

Differential Shunt Feature.—The differential shunt type meter involves a principle of operating for obtaining any desired percentage of overcharge. This meter is used on straight storage cars where the battery is not floated on the line. It cannot be used in any system where the generator must supply current to lamps on the battery circuit at the same time it is charging the battery.

The arrangement of the differential shunt with the simple ampere-hour meter element is as shown in the diagram, Fig. 93. The principle of operation is that a greater drop is obtained from the shunt in a discharge circuit than in the charge

circuit so that the meter will run relatively slower on charge, on a given load, than on discharge. By means of suitable bridging connections on the shunts, and a sliding adjustment, it is possible to maintain the meter correct on discharge, and to change the adjustment by any desired percentage slow on charge. With this arrangement of differential shunt, assuming that the indicator of the meter has recorded true ampere-hours discharge, the meter will run slow on charge so that when the indicator has returned to its

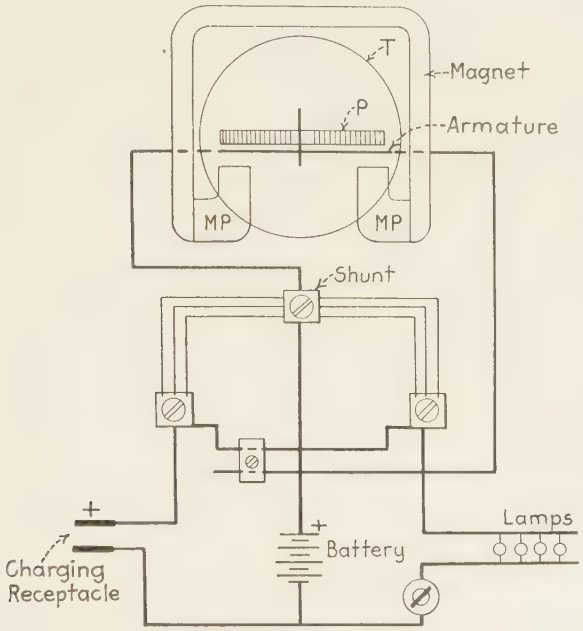


FIG. 93—Circuit Diagram of Differential Shunt Type Sangamo Ampere-Hour Meter.

original position, necessary overcharge will have been given and the battery will again be at full when the indicator hand shows at that point.

Manual Reset.—The simplest means of compensating for overcharge is of the non-automatic type; it depends upon the manual resetting of the indicator hand by the battery operator. In this case, the simple type of meter, without resistor or differential shunt is used, and the indicator hand is provided with a mechanism

accessible from outside the meter cover, by which the hand can be set at any desired point before or after the charging process is started. The resetting device is also very useful on meters having either differential shunt or variable resistor, as it is necessary from time to time to give any storage battery a special overcharge, and in such cases a predetermined amount of charge may be given by simply setting the indicator hand ahead to any desired point by means of the resetting device.

Stop-Charge Feature. With ampere-hour meters in car lighting service it is usually desirable to have some means of automatically stopping the charge when the indicator hand has returned to the full-charge point. For this reason the Sangamo ampere-hour meters designed for such service have an insulated contact placed at the zero or full charge point on the dial. When the hand reaches this point a shunt trip circuit breaker may be operated, automatically discontinuing the charge. In addition to the contact at full-charge point, it is sometimes desirable, and in many cases necessary, to have one more contact at another point on the dial of an ampere-hour meter in order to operate relays to discontinue discharge and start a recharging operation. This second contact may be placed at any ampere-hour discharge point on the meter dial.

Method of Increasing Light Load Accuracy and Compensation of Internal Battery Losses. As the use of ampere-hour meters became general in railway train lighting, it was found necessary in many cases to reset the indicator hands of meters, even when equipped with differential shunts or variable resistors, so as to give overcharge quite frequently to compensate for internal loss in a battery when standing idle or for current not registered by a meter at very small fractions of rated load. To compensate for this, a thermo-couple, shown in Fig. 94, is used in Sangamo meters. This thermo-couple consists of two pieces of dissimilar metal brazed together, and heated by a fine wire resistance winding connected across the circuit in which the meter is placed, so that a very low difference of potential is set up in the thermo-couple. Having the terminals connected through a suitable adjusting resistance to the motor element of an ampere-hour meter, a current will pass through the armature from the thermo-couple, which, when properly adjusted in volume, will

cause a slight continuous rotation of the meter disc, thus recording on the dial and compensating for internal loss in a battery standing idle. Aside from this, the least amount of load current passing through a meter with such compensation, will be accurately measured as the armature is in rotation without the load current on, and will therefore increase in speed of rotation in direct proportion to the least current flow in a circuit in which the meter may be connected. By using the thermo-couple in a Sangamo ampere-hour meter, the indicator of the meter will be kept in perfect step with the condition of the battery with respect to

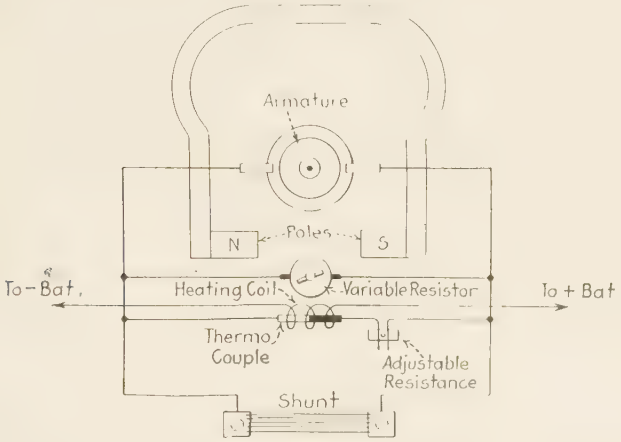


FIG. 94—Thermo-Couple and Resistance, Connected in Multiple, With Armature Circuit Heating Coil Connected Across Battery Terminals.

charge, over very long periods, without periodical overcharge, as would otherwise be required.

Application of Sangamo Ampere-Hour Meters.—The auto-base type of Sangamo ampere-hour meter is used with the three general classes of car lighting equipment, namely:

1. Axle generator equipment.
2. Head-end generator equipment.
3. Straight storage equipment.

The term "auto-base" was given many years ago when meters of this form were originally brought out for use on electric automobiles; aside from this, the designation has no special meaning. The auto-base meter has an aluminum base for the operating

parts, with black enameled metal cover and connections brought out either as back extending studs or bottom connecting cables.

Application with Axle Generator Equipment.—The axle generator equipment includes a generator on each car which is driven from the car axle so as to keep the battery on the car at as nearly full charge as possible; meanwhile the battery carries the load below a certain critical speed. With this equipment the ampere-hour meter has proved extremely valuable in preventing excessive battery overcharge. This is accomplished by means of the full-charge contact in the ampere-hour meter. As now applied, when the ampere-hour meter hand reaches the full-charge point, it operates through a relay or other equivalent device to change the

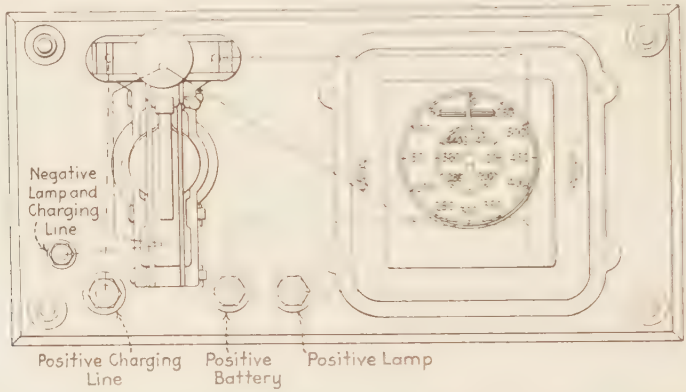


FIG. 95—Control Panel With Meter and Circuit Breaker. Electrical Connections Shown by Dotted Lines.

field strength of the generator so that the charge to the battery is reduced to zero and the battery floats, or is approximately at that point. The battery continues to float while the train is above critical speed, and then after the next stop, charging is resumed until the battery again reaches full-charge point when the operation repeats, preventing excessive overcharge. There are various modifications in several types of axle generator equipments which may require in individual cases certain changes in the arrangement of the full-charge contact, and with one or two types of equipment a restoring contact is required at a certain point of discharge, so that relays may be operated by the two contacts.

Sangamo Meters with Straight Storage Equipment.—In

addition to the application of the Sangamo ampere-hour meter as automatic control of the battery charge with axle equipment as now used on railroad cars in the United States and Canada, they have been used for many years on several railroads having straight storage battery lighting equipment; that is, where the lights are supplied by a battery on the car, which is charged at terminal points, but with no generator on the car itself. In this service the meter records total discharge while the battery is carrying the load of lights, fans, etc., on the car, and indicates total charge plus the necessary overcharge when the battery is charged at terminal points. Meters for this service are frequently equipped with Sangamo circuit breakers on a panel arranged for installation in lighting cabinets of the car, as shown in Fig. 95.

Sangamo Meters with Head-End Equipment.—With head-end equipments, where the generator is carried in the baggage car or on the locomotive, it is necessary to use a somewhat different arrangement of meter and relays, if automatic control is desired. On a number of railroads having head-end equipments, meters with duplex gear trains are used to keep track of the condition of the battery on each car, but not to give automatic control of the battery charge.

Fundamental Principles of Application.—The fundamental principles in the application of Sangamo meter control may be divided into three general classes:

(a) Those in which the meter indirectly controls a resistance in series with the generator field. (b) Those in which the meter, either directly or indirectly, controls a resistance in series with the voltage controlling solenoid. (c) Those in which the meter indirectly controls a resistance which acts in parallel with the generator field.

Fig. 95 shows a Sangamo control panel for use on either straight storage or axle generator cars. With either system the circuit breaker controls the external charging circuit only, that is, the charging from a yard plant, and has no connection whatsoever with the charging line from the axle generator.

Other control panels consisting of a circuit breaker and two ampere-hour meters having a rating of ten and sixty amperes respectively are also used. The meter with the ten-ampere rating registers the current on discharge, and the one with the sixty-

ampere rating registers the current on charge. These meters are of the simple shunt type and are equipped with the manual resetting device. The circuit breaker controls the charging circuit only. This panel is designed for use in cars having a very small lamp load such as refrigerator cars. The operation of this panel is as follows:

Assuming a fully charged set of batteries are applied, the pointer of the discharge meter should be set by hand at zero. When necessary to charge the battery the hand of the charge meter should be set to the ampere-hours indicated on the discharge meter, and the circuit breaker closed. As the batteries are charged the hand will rotate counter clockwise and when charging is completed the hand will close the contact at the zero point, opening the circuit breaker and cutting off the charge. If the charge is complete, the needle on the discharge meter should be set by hand

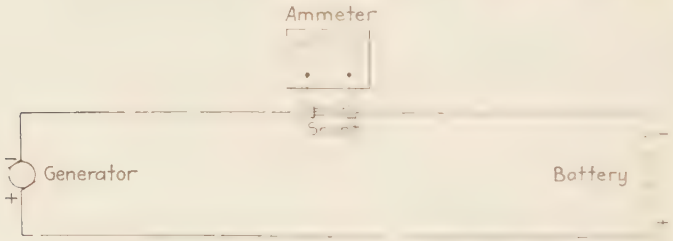


FIG. 96—Method of Connecting an Ammeter in the Main Circuit.

at zero, or, if not complete, at the ampere hours indicated by the hand of the charge meter.

Sangamo Circuit Breaker. The Sangamo circuit is extremely simple. It contains two sets of contacts, one set for controlling the main battery charging circuit and a smaller set for controlling the breaker shunt coil circuit. The breaker is operated by this shunt coil which is energized by the operation of the zero contact on the Sangamo meter dial. The shunt coil operates the breaker by tripping a latch. This latch when closed will stand such jarring and vibration as is encountered in train operation without allowing the breaker to open and yet as soon as the shunt coil is energized, it opens instantly and positively.

Quick-Break Contact.—A new type of break contact is now in use which is a big improvement over the older type of contact. In

this newer design the meter dial hand, instead of simply making a butt contact as it comes around to the zero point, engages a dog which is pivoted and bears against a spring carrying a platinum contact, causing it to make contact with a similar platinum point above, thus closing the control circuit. After the dial contact has been made and battery charging discontinued, the meter is no longer driven in a charging direction. Accordingly, the contact remains closed until the battery has discharged so that the meter hand moves back to the 50 ampere-hour mark on the dial at which time the operation of the device causes the meter dial contact to open instantaneously.

Connecting a Sangamo Ampere-Hour Meter in a Circuit.—A direct-current ammeter is used in testing axle generator equipment. This instrument indicates the amount of current in amperes that is flowing in the circuit. If the ammeter indicates that the battery is receiving a charging current of 40 amperes, and the charge continues for one hour, the battery has received forty times

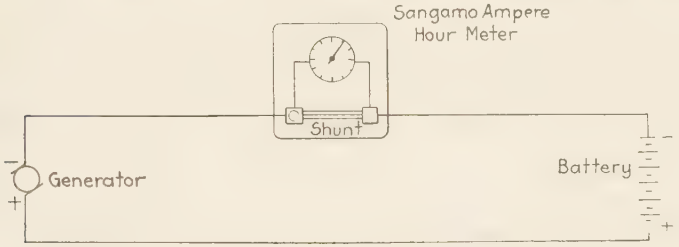


FIG. 97—Method of Connecting a Sangamo Ampere-Hour Meter in the Main Circuit.

one or 40 ampere-hours charge. This is exactly what the ampere-hour meter does, it multiplies current and time, and the product in ampere-hours is indicated by a hand which is moved around a graduated dial.

The direct-current ammeter in general use for testing axle generator equipment is of the external shunt type. This type of ammeter is very convenient for this particular work because the shunt can be equipped with blades and inserted in place of the generator fuse, thereby eliminating the necessity of disconnecting wires from the apparatus. Fig. 96 shows the method of connecting a direct-current ammeter to measure the current in the gen-

erator and battery circuit. The shunt is inserted in series with the circuit and two flexible wires connect the instrument directly across the shunt.

A Sangamo ampere-hour meter is connected in such a circuit in like manner. The shunt is connected in series with the circuit and the various meter circuits are connected by small conductors across the shunt as shown in Fig. 97. The indicating mechanism of an ampere-hour meter is different from that of the ammeter in that it contains a means for revolving a train of gears which in turn moves a hand over a graduated dial.

CHAPTER X

MORE ABOUT THE AMPERE-HOUR METER

The use of the ampere-hour meter is so extensive that a discussion of the theory involved in its operation is a valuable supplement to the description of its construction as contained in the preceding chapter.

A circuit diagram of a simple-shunt Sangamo ampere-hour meter is shown in Fig. 98 with the principal meter parts marked as follows:

P—armature element.
M—permanent horse shoe magnet.
MP—magnet poles.
S—shunt.
T—gear train.
D—damping disc.

The theory of the operation of the armature element is similar to that of a wire carrying current, and placed in a magnetic field; the wire tends to move out of that field in a direction perpendicular to the lines of force and perpendicular to its own axis. This is due to the reaction between magnetic lines of the field and the magnetic lines emanating from the wire carrying the current and is the same principle which makes a motor armature revolve. The force with which this wire will move out of the magnetic field depends upon the strength of the field and upon the amount of current flowing through the wire; with the field constant, if the current through the wire be doubled, it will move with twice the force, etc.

The permanent horse shoe magnet in the Sangamo ampere-hour meter has two poles, designated north pole and south pole. These poles are placed one on each side of the axis of the armature, so that the current passing across the copper disc armature encounters two magnetic fields, the magnetism of one field being directly opposite in direction to that of the other. The current going through

the armature reacts with a magnetic field of south polarity on one side of the axis and with the magnetic field of north polarity on the other side of the axis of the armature. The effect of these two forces acting in opposite directions at opposite sides of the armature, causes the latter to rotate. The strength of the permanent horse shoe magnet is constant, therefore the speed at which

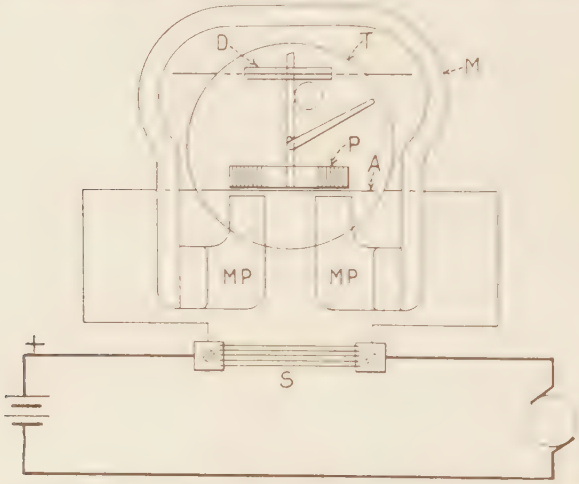


FIG. 98—Circuit Diagram of Simple Shunt Sangamo Ampere Hour Meter.

the armature rotates depends upon the strength of the current through the armature.

The direction of armature rotation is governed by the same rule that applies to a direct-current shunt-wound motor as follows:

1. If the polarity of the field is changed, the armature will rotate in the opposite direction.
2. If the polarity of the armature is changed, the armature will rotate in the opposite direction.
3. If the polarity of both the armature and field is changed, the armature will rotate in the same direction.

In the Sangamo ampere hour meter the polarity of the field—which is the permanent horse shoe magnet—never changes, therefore the direction of armature rotation depends upon the direction of the current through the armature. The charging current to the battery passes through the meter shunt in one direction and the battery discharging current passes through the shunt in the oppo-

site direction. The armature circuit is connected in parallel with the shunt circuit, therefore the direction of current through the armature will be the same as that of the shunt and the direction of armature rotation will be governed accordingly.

The damping disc rotates in the field of another permanent magnet and operates as a generator. The torque required to turn this aluminum disc is directly proportional to the speed and as the armature and damping disc are fixed to the same shaft the speed of the disc is proportional to the torque, which is in turn proportional to the current through the armature. The current can therefore be measured by counting the revolutions of the damping disc, each revolution being equivalent to a definite quantity of current. In other words, the damping disc controls the meter so that it will run at a speed directly proportional to the amount of current flowing through the armature.

The variable resistor element is connected electrically in parallel with the shunt and the armature circuits. Therefore the strength of the current through the armature will depend upon the resistance of the shunt and the variable resistor circuits. The resistance of the shunt is constant, but the resistance of the resistor circuit varies. This variation is effected as follows: The permanent horse shoe magnet that furnishes the field for the armature element also furnishes a magnetic field for the resistor element. The reaction of the current flowing through the pivoted copper bar with the field of the horse shoe magnet causes the resistor bar to rotate. This rotating effect involves the same theory as that of the armature, but in this case the rotation is limited to a slight angle by an adjustable stop in the resistor chamber. When the current through the resistor element reverses from a charge to a discharge direction or vice versa, the resistor will rotate in the reverse direction until it strikes the other stop. An adjustable dial at the bottom of the resistor element connects through the chamber to a circular plate carrying the two stop pins, which limits the movement of the resistor bar. A graduated scale is provided so that the position of these pins may be adjusted to cause the meter to operate at any percentage of battery overcharge desired between the limits of zero and thirty per cent. The resistance of the resistor element circuit is varied by moving the pivoted copper bar of the resistor element in and out of the line of the contacts

through the resistor. When the bar is directly in line with the terminals of the resistor element, the current passes from one terminal of the resistor element to the other through the copper bar giving the circuit its minimum resistance. When the resistor bar moves in the opposite direction out of the line of contact, it is necessary for the current through the resistor element to pass through a short section of mercury at each end of the resistor bar. The resistance of the resistor circuit will then be at its maximum value because the resistance of mercury is approximately sixty times greater than that of copper.

As stated, the resistor circuit is in parallel with the armature circuit, therefore an increase in resistance in the resistor circuit will send more current through the armature, causing the meter to run faster. Likewise a decrease in the resistance of the resistor circuit will shunt some of the current out of the armature circuit and cause the motor to run slower. The variable resistor element is adjusted so that the meter will record true ampere-hours on discharge and run from ten to thirty per cent slow on charge.

The theory of the thermo-couple involves the principle that when two unlike metals are welded together and heat applied to the joint, a potential is generated by the action of the heat on the joint. Then when the cold ends of the welded piece are connected to an electrical circuit, a current will flow just in the same manner as if the thermo-couple were a storage battery or a generator. The thermo-couple for Sangamo ampere-hour meters consists of two unlike metals welded together and connected across the armature circuit in series with an adjustable resistance. The heat is applied to the joint by means of a small electric heating coil which is wound around the joint of the two metals, and connected across the battery terminals. The potential that is generated by the heating of the joint sends a small current of approximately one-half ampere through the meter and causes the meter to creep in a discharge direction. Current for operating the heating coil is taken either from the battery terminals direct or from the outside of the main lamp switch, as desired. In the first case, the meter will creep all the time, and in the latter, will creep only when the lights are on, the current being recorded on the meter.

Testing Sangamo Ampere-Hour Meters. Sangamo ampere-hour meters should be tested at least once a year. The instruments

required for testing are a direct-current ammeter and a stop watch. As previously stated, ampere-hour meters of the differential shunt or resistor type are set slow on charge and correct on discharge Therefore, before proceeding to test the meter it should be determined whether the meter is correct in the discharge direction. In making this test, the ammeter should be connected in series with the Sangamo ampere-hour meter, as shown in Fig. 99, and the current through the meter adjusted so that it will be constant through the period of test. The speed of the meter in the direction in which it is set correct—in this case, on discharge—is ten revolutions in thirty-six seconds at full load. The majority of Sangamo ampere-hour meters for train lighting service are rated at sixty amperes, therefore the correct speed of this meter would be ten revolutions in thirty-six seconds at sixty amperes. In checking the accuracy of a meter, the following formula should be used:

$$S = \frac{K \times R}{I}$$

Where K equals the constant of the meter under test, R equals the revolutions observed; I equals the load in amperes, and S equals the correct time in seconds for R revolutions. If the observed time does not correspond with the time as calculated from the above formula, the percentage accuracy can be determined by dividing the correct time by observed time, that is, if S_1 is the observed time, the percentage accuracy will be $\frac{S}{S_1}$. The constant of a ten-ampere meter is 36, and is directly proportional for other sizes unless otherwise marked on meter in special cases. For example, the constant of a sixty-ampere hour-meter would be

$$\frac{60}{10} \times 36 \text{ or } 216$$

This constant is for the speed on discharge where the meter is set correct on discharge. If upon test the meter is found to be incorrect, it may be adjusted by varying the position of the soft iron disc located over the jaws of the permanent magnets. Raising this disc decreases and lowering it increases the speed of the meter. On light loads, that is, ten per cent of the rate of capacity

of the meter, the accuracy will usually be found to be within three per cent. Unless the meter is equipped with a thermo-couple, there is no adjustment for light load accuracy, and if the error at this load exceeds three per cent, it is advisable to clean the mercury thoroughly. Very often it will be found that there are filings or other particles of foreign matter in the magnet air gap, which drag upon the disc, resulting in the meter slowing down on light load. Therefore, before taking the meter apart, the air gap should be thoroughly clean. When the horse shoe magnet is removed from the meter, a keeper should be placed across the pole tips in order that it may retain its magnetism.

The percentage slow on charge should not be confused with the percentage overcharge, as these two quantities have entirely different values. In order to determine the percentage slow on charge or the percentage overcharge, the following formulæ should be used:

$$\text{Percentage slow on charge } \frac{S_1 - S}{S_1}$$

$$\text{Percentage overcharge } \frac{S_1 - S}{S}$$

The following table will also be of use in determining the percentage overcharge, knowing the percentage slow on charge, or vice versa:

Percentage Slow on Charge.	Percentage Overcharge.
15	17¾
16⅔	20
20	25
25	33⅓

The following formula and illustration may assist in making the foregoing more clearly understood:

$$KR = IS \quad K = \frac{IS}{R} \quad R = \frac{IS}{K} \quad I = \frac{KR}{S} \quad S = \frac{KR}{I}$$

In the formula K equals the constant; R, the revolutions; I is current, and S is time in seconds for R revolutions.

Consider a mercury motor, variable resistor type Sangamo ampere hour meter, with a rating of 60 amperes: Given, K (con-

stant) 216, to find the S (time) for 10 revolutions. To calculate this time, first select the formula with the unknown quantity to the left of the equality sign, which in this case is $S = \frac{KR}{I}$. The solution would be

$$S = \frac{216 \times 10}{60} = 36 \text{ seconds}$$

Therefore, the correct adjustment of this meter will be 10 revolutions in 36 seconds with a current of 60 amperes flowing through the meter.

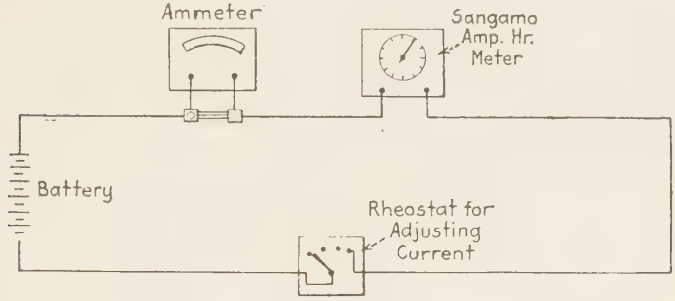


Fig. 99—Sangamo Ampere-Hour Meter Connected for Test.

It has been stated that a Sangamo ampere-hour meter for storage battery operation was adjusted correctly on discharge and slow on charge to compensate for battery efficiency. Assume in this case the battery efficiency to be 80 per cent. The meter speed on charge should therefore be 80 per cent of the discharge speed with the rated current of 60 amperes flowing in each case. If the time for 10 revolutions on discharge is 36 seconds, and it is desired to compensate on charge for 80 per cent battery efficiency, the correct time for 10 revolutions with 60 amperes flowing on charge would be:

```
.80 ) 36.00 ( 45 seconds
      32 0
      ----
       4 00
       4 00
       ----
```

A meter so adjusted is only recording a battery charging current

of 48 amperes, although 60 amperes is actually flowing through the meter. This current of 48 amperes is obtained by using the formula $I = \frac{KR}{S}$ with S as 45 seconds instead of 36.

Starting with the battery in a fully charged condition and the hand on the Sangamo meter at the full charge point, suppose we discharge the battery through the meter at a 60 ampere rate for eight hours. The ampere-hour meter hand should now indicate that 8×60 or 480 ampere-hours has been taken from the battery. Now, as this meter only records a current of 48 amperes on charge when a current of 60 amperes is flowing through the meter, it would require an actual charge of 10 hours at 60 amperes, or 600 ampere-hours, to move the hand back the 480 ampere-hours to the full charge point on the meter dial. In other words, the battery receives an overcharge of 600 less 480, or 120 ampere hours. Figuring this on a percentage basis, the battery received on overcharge of $\frac{120}{480}$ of 100 per cent, or 25 per cent. A Sangamo ampere-hour meter should therefore be adjusted for a 25 per cent overcharge to keep in step with a battery operating at 80 per cent efficiency.

Graphic Ampere-Hour Meter for Car Lighting Service.—The graphic ampere-hour meter, Fig. 100, is designed to give a definite indication of the treatment which any storage battery receives, both as to current rate and time of charge and discharge, and the more important information as to the actual condition of battery charge at any time. This meter is useful in checking the operation of all types of axle car lighting equipments and, since it requires no more attention than to simply install it in circuit and wind the clock once a week, it is no doubt a very useful and practical instrument in car lighting service.

The operation of a graphic ampere-hour meter is as follows: The meter consists of a standard ampere-hour meter of the variable resistor type with the zero contact removed. A sheave is mounted on the main shaft of the dial hand immediately back of the dial and the small German silver chain A makes several turns around this sheave and is permanently connected to it. As the main dial hand of the meter slowly revolves, its motion is

transmitted by means of the chain to the recording pencil *B*. This is mounted on a rolling carriage and moves with very little friction on a meter track which serves also as a guide for the carriage. The sheave mounted on the main shaft of the meter is so designed as to give a horizontal movement of the carriage of 1/16

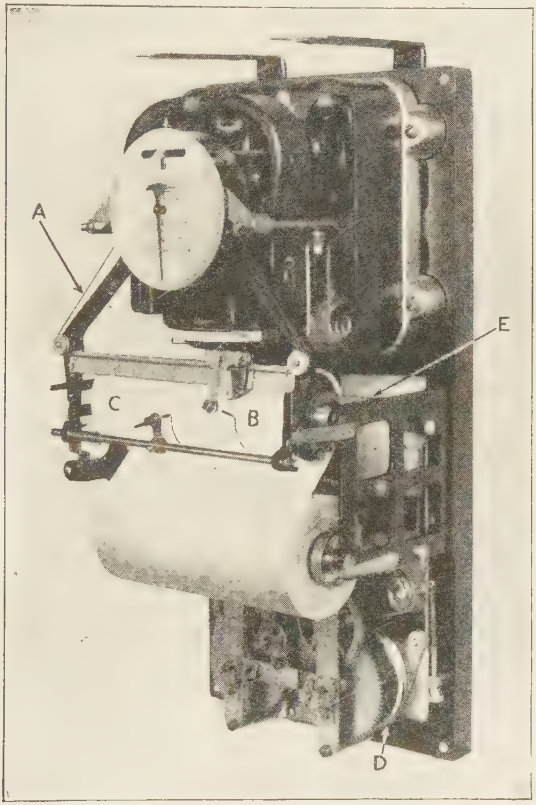


Fig. 100—Graphic Ampere-Hour Meter With Case Removed Showing Recording Pencil (B) Mounted on Rolling Carriage Moved Horizontally by Ampere-Hour Meter Gear Train.

in. for every 10 ampere-hours indicated on the meter dial. A movement of the carriage pencil *B* of 1/16 in. in a discharge direction would then represent 10 ampere-hours discharge, while a movement of the carriage in the opposite or charging direction of 1/16 in. would represent 25 per cent more than this—if the resistor element is set at this value—or 12½ ampere-hours. It might be thought

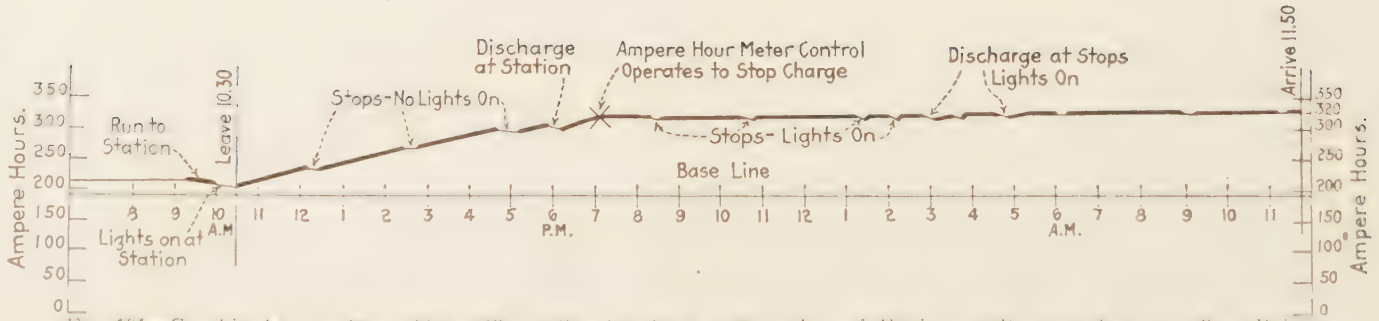


FIG. 101—Graphic Ampere-Hour Meter Chart Showing Proper Operation of Equipment Running Between Two Points. Heavy Section of Curve is Caused by Vibration Due to Moving Train, Light Sections Indicate Stops.

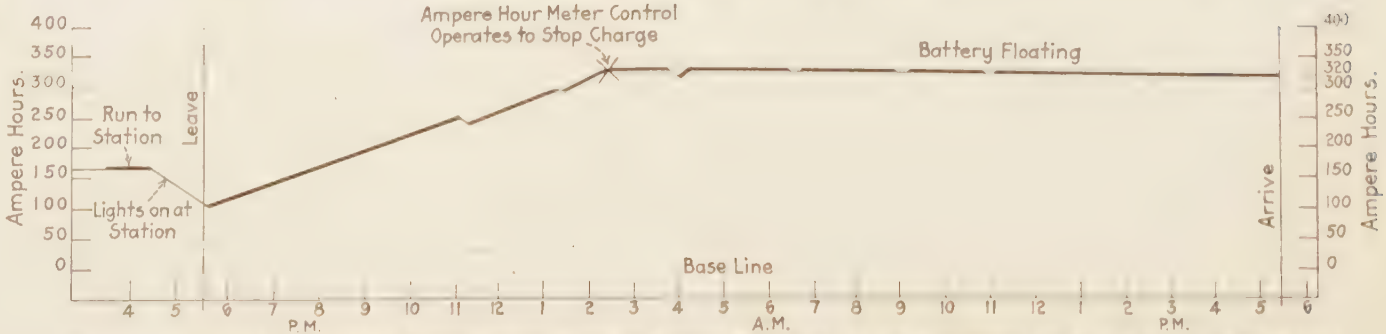


FIG. 102—Graphic Ampere-Hour Meter Record Showing Proper Operation of the Equipment on Run Between Two Points. Horizontal Section of the Line Indicates Battery Floating at Full Charge.

that this removable carriage for the recording pencil would add sufficient friction to cause the meter to record inaccurately; mercury meters of this type, however, have a very high torque which, acting through the reduction gear, gives a torque on the main dial shaft equal to 3 foot pounds. Theoretically this would require a friction of 75 lb. to stop the pencil carriage.

The pencil is adjustable and is usually sharpened with a flat point so as to give a fine line, and at the same time have long wearing qualities. It is supported from the movable carriage by means of a substantial spring arm which provides proper pressure of the pencil on the paper upon which the record is made.

The stationary pencil *C* is for the purpose of giving a base line on the second sheet. This may be set at any point desired and an adjustable spring provides proper pressure of the pencil on the paper. This base line has no reference whatever to the zero capacity of the battery. It should also be considered that full batteries are under consideration instead of empty ones.

A substantial eight-day clock movement, as shown at the bottom of the meter, operating through the drum *D* and cord *E*, furnishes power which moves the recording paper. The speed of motion is adjusted to approximately ¼ in. for every half hour. One foot of record tape will then represent a whole day's run, and a week's run would require only seven feet of tape. Every half hour the clock mechanism strikes, and in doing so, causes the base line pencil *C* to move transversely on the paper about ⅛ in., giving the marks of time on the base line. This automatically records the time of operation and by marking on the tape the time of starting the test, the exact time at all points on the curve is obtained.

Application of Graphic Meter. –The record of battery charge and discharge on a car running between two points is shown in Fig. 101. It will be noted that when the car is not in motion the graph of the recording pencil is light, but as soon as the car begins to move, whether the equipment is generating or not, the line becomes heavy; in this way practically all of the stops are indicated. As mentioned before, the base line has no reference whatever to the battery capacity scale, but simply gives a base line from which values of charge and discharge can be measured. For illustration, it has been assumed in the curve, that the capacity of the battery when fully charged, as it was from 7 p.m. to the end of a run,

FIG. 103—Graphic Record Showing the Operation of Same Equipment as Fig. 102 but Without Ampere-Hour Meter of Voltage Control of Charge.

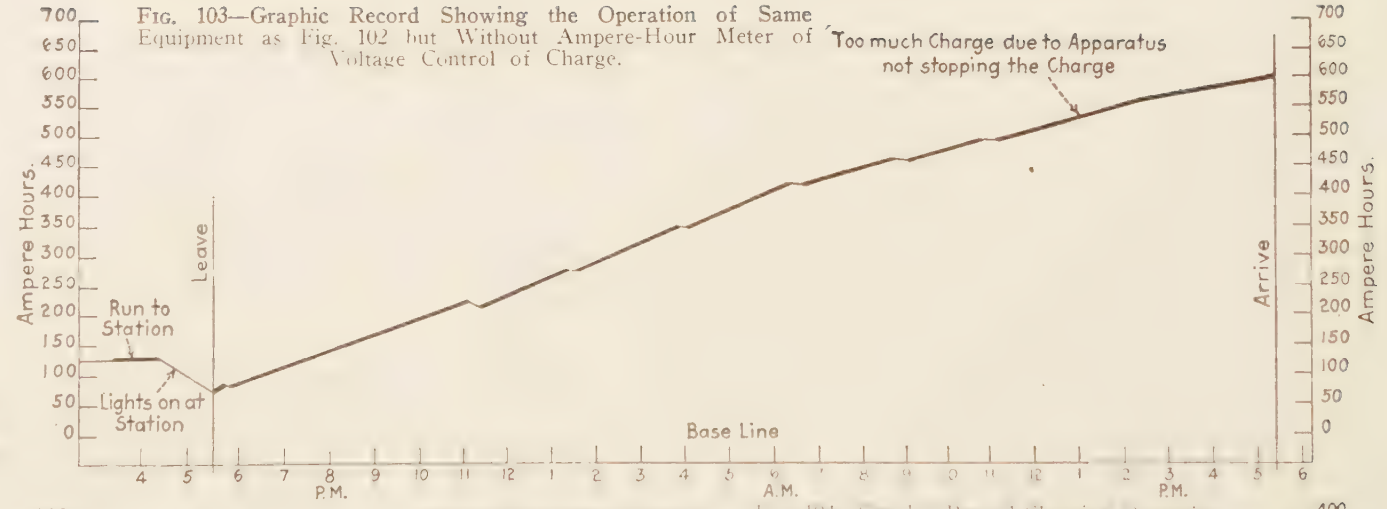
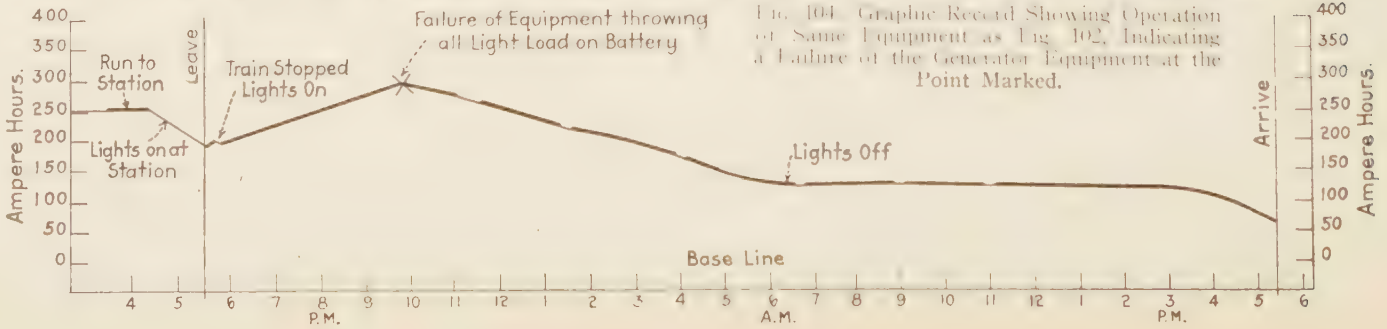


FIG. 104—Graphic Record Showing Operation of Same Equipment as Fig. 102, Indicating a Failure of the Generator Equipment at the Point Marked.



is 320 ampere-hours. Since 1/16 in. equals 10 ampere-hours, the vertical scale can easily be figured. This scale has been placed at each end of the curve. The curves as recorded by the meter, however, are simply the two lines shown heavy.

While standing in the yard there was a capacity of 215 ampere-hours in the battery. The run to the station is shown by the heavy horizontal line and discharge now begins as indicated by the downward curve of the line. Altogether enroute to and at the station the battery discharged 10 ampere-hours. As soon as the train left the station, the battery started to charge, and this is indicated by an upward slope of the line; since this equipment was set for constant battery current regulation, the upward slope of this line is always at the same angle. If this had been a constant generator current regulator, this degree of slope would have varied depending upon the charging current rate.

It will be noted that during the daylight stops there was no discharge and the light lines, indicating stops, are horizontal. After the point corresponding to sunset the light lines at all stops slope downward, this indicating a discharge at each stop. As soon as the equipment begins to generate again, however, the curve again begins its upward slope, indicating that the battery is charging at the constant rate of the regulator setting. At 7 p.m., indicated by a cross on the curve, Fig. 101, the battery has reached a full state of charge, and since this equipment was controlled by an ampere-hour meter of the variable resistor type, this meter, like the graphic meter, indicated a zero discharge and thereupon closed its zero contact which stopped further charging of the battery. The battery then simply floated on the line, the generator carrying the load of whatever lamps happened to be in use at the time. It will be noted that there are various stops where a slight discharge occurred, but this was quickly replaced by normal operation of the equipment and the controlling meter again operated to stop further charge when the discharge plus 25 per cent had been put back into the battery.

Fig. 102 is another chart showing the operation of an axle generator car lighting system with the generator regulator adjusted so as to provide constant battery current; the charge given a battery is controlled by an ampere-hour meter of the variable resistor type. As in Fig. 101, there is a very normal condition of

affairs with the battery charging normally enroute, a few short discharges at stops, and finally coming to a state of full charge at 2.30 a.m., when the controlling ampere-hour meter operated to stop further charge, and so protect the battery from excessive overcharge.

In Fig. 103 both the controlling ampere-hour meter and the voltage regulating solenoid were purposely cut out of service and the equipment operated as on a simple constant battery current control. This illustrates, of course, only abnormal conditions such as would be experienced in using a regulator of the constant current type without auxiliary control of charge; or when the voltage regulating feature of the combination current voltage regulators without ampere-hour meter control; or when both the ampere-hour meter and voltage regulation of equipments with the ampere-hour meter control fail to work. In this run a charge of 525 ampere-hours was given a 320 ampere-hour battery, which at the start showed only a 245 ampere-hour discharge. This indicates an overcharge of 280 plus 25 per cent, or 350 ampere-hours, representing the full normal charging rate for nearly nine hours on this single run. When considering the effect of such serious overcharging on a battery, it is not surprising that the average battery life in car lighting service has been so short before the use of voltage regulators giving a taper charge or the controlling ampere-hour meter came into use.

Fig. 104 shows another abnormal condition wherein the equipment failed to generate on the point marked "x" on the curve, due either to lost belt which was not replaced or trouble on the equipment. It will be noted that there is a continual discharge on the battery from this point till the end of the run; this does not follow a straight line, but tapers more to the horizontal as the number of lamps in use is reduced.

The graphic ampere-hour meter is also very useful in recording the effect of tapered charging with the combination current voltage, and also on the constant voltage types of regulation under various conditions of winter and summer operation. Its use is also a big help in determining the proper floating voltage for the battery at various times of the year.

CHAPTER XI

LIGHTING CIRCUITS AND FIXTURES

Considering their importance, car lighting circuits and fixtures should be designed with an aim for mechanical strength as well as electrical efficiency. This includes distribution panels, switches, lamps, fans, etc. A distribution panel for passenger car lighting is shown in Fig. 105. This is one of a variety of panels

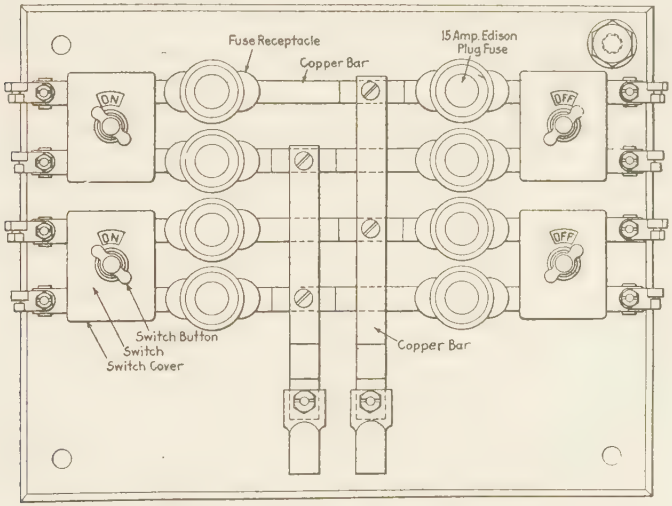


FIG. 105—Crouse-Hinds Control Panel for Passenger Cars.

for car lighting service and is equipped with switches and fuses for four individual lighting circuits. The lighting circuits are carried overhead in conduits, either under or on top of the roof. Fig. 106 shows a conduit diagram of a day coach. In this case

the conduit is on the roof with a junction box opposite each lighting fixture.

Car Lighting Fixtures.—Car lighting fixtures are of special construction to meet the exacting conditions of railway service. They are designed to some extent artistically, but more stress has been laid on the mechanical and illuminating features. A wide

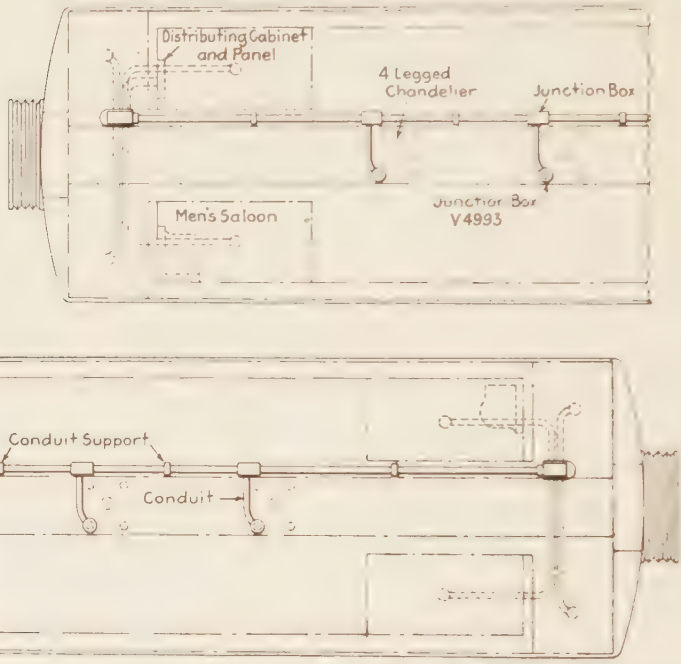


FIG. 106—Conduit Diagram—Conduit Over Roof for Lighting Circuits.

variety of fixtures are in use today for car lighting service, and there is also a variety of reflectors and glassware in combination with the various lighting fixtures. The car lighting engineers have been giving specialized study to the science of illumination, consequently the manufacturers of glassware have produced a great variety of shapes, colors and compositions in lighting glassware.

When electric car lighting was introduced the cars were made of different material and of different design than those of today.

The fixtures were more ornamental than serviceable. When the steel car arrived the car lighting engineers realized the importance of units that would not only generate light efficiently but give efficient illumination also. One has only to compare the old with the new to appreciate the great progress that has been made in car illumination.

There are many different types of cars on the railroads—day coaches, dining car, mail car, baggage car, parlor car, sleeping car, etc. The type and location of the lighting fixtures depend upon the type of car, as a fixture or reflector suitable for one class of car would not do for another. There are, however, three general systems of car lighting in use.

1. Center deck fixtures mounted along the center line of the car.
2. Large number of small fixtures mounted on the half deck or clere-story.
3. Combination of center and deck fixtures.

Day Coach Lighting.—Single unit fixtures with open reflectors are in general use in day coaches. The lamps are either hung from the ceiling in a single row along the center line of the car, or in two rows on the deck. The single row in the center has the advantage over the double row in the deck, in that it does not require as many lighting units and gives better illumination for passengers to read.

Pullman Car Lighting.—The illumination of Pullman cars requires more study than that of the day coach because the appearance of the fixture from an artistic standpoint is a big factor. For this reason the indirect, semi-indirect and luminous fixtures, as well as the open reflector type, are in use. The fixtures in sleeping cars are placed in a single row down the center line of the car and, in addition, each berth is illuminated by two small reading lamps. Sleeping cars are also equipped with aisle night lights which are used to illuminate the aisle when the center lights are switched off. They are located under the seat ends.

Pullman parlor and club cars are illuminated on the same principle as the sleeping car, with the exception that they have small lamps along the deck over the chairs instead of the berth lamps.

The fixtures in dining cars are usually located in a single row

down the center line of the car with the addition of small bracket lamps on the side walls over the table.

Postal cars are equipped with fixtures in a single row down the center line of the car and over the letter cases. The post office

FIG. 107—Various Types of Fixtures for Postal and Mail Storage Cars.

department specifications call for a certain amount of light at the various stations throughout the car, therefore the efficiency of the lighting units must be maintained to comply with these specifications. Fig. 107 shows a variety of units for postal and mail storage cars.

Private and business cars are illuminated in very much the same way as the various Pullman cars, but generally the fix-

tures are designed with an aim for a pleasing appearance more than illuminating efficiency.

Train Lighting Lamps.—Train lighting lamps are subjected to violent vibration and therefore require more rugged construction than incandescent lamps used for other purposes. There are two types of train lighting lamps in use today, the mazda B lamp and the mazda C lamp.

The mazda B lamp is a vacuum type lamp with a tungsten filament, and is used in various sizes and shapes. Referring to the table and to Fig. 108 it will be noted that the mazda B lamps are used in sizes ranging from 10 to 50 watts and with four different sized and shaped bulbs. It will also be noted that the 50-watt

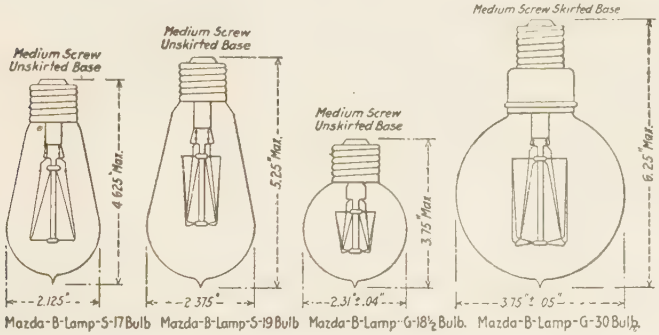


FIG. 108—Mazda "B" Train Lighting Lamps—Bulb Classification.

mazda B lamp generates approximately 500 lumens of light or 10 lumens per watt of power consumed.

The mazda C lamp is a gas filled lamp and is also used in various sizes and shapes. The train lighting lamp table shows that these lamps are used in sizes ranging from 50 to 100 watts and with three different sized bulbs, as shown in Fig. 109.

The mazda C lamp has an advantage over the mazda B lamp, having a higher efficiency. In other words, the mazda C lamp gives more light per watt of power consumed than the mazda B lamp. For example, we stated above that the 50-watt mazda B lamp generated approximately 10 lumens per watt of power consumed. By referring to the train lighting lamp table it will be seen that a 50-watt mazda C lamp generates 739 lumens of light,

or approximately 15 lumens per watt of power consumed, which is, indeed, an improved efficiency.

Classification of Bulbs. The numbers and letters that are used to designate the various shaped bulbs may appear confusing at first sight, but a little study of Figs. 12 and 13 will illustrate the following: The round bulbs are marked with the letter *G*, meaning globular. The straight side bulbs are marked with the letter *S*, meaning straight side. The pear shaped bulbs are marked with the letters *PS*, meaning pear shaped.

The numbers designate the extreme diameter of the bulb, expressed in ⅛″ units as follows:

S-17 bulb is 17 x ⅛″, or 2.125″
S-19 bulb is 19 x ⅛″, or 2.375″
G-18½ bulb is 18½ x ⅛″, or 2.31″
G-30 bulb is 30 x ⅛″, or 3.75″
P-20 bulb is 20 x ⅛″, or 2.5″
P-22 bulb is 22 x ⅛″, or 2.75″
PS-25 bulb is 25 x ⅛″, or 3.125″

TABLE OF TRAIN-LIGHTING LAMPS

Standard Schedule

Watts	Volts	Lamp	Bulb	Lumens	Lumens per watt
10	30–34	mazda "B"	S–17	94	9.4
10	30–34	mazda "B"	G–18½	87	8.7
15	30–34	mazda "B"	S–17	144	9.6
15	30–34	mazda "B"	G–18½	137	9.14
25	30–34	mazda "B"	S–17	244	9.76
25	30–34	mazda "B"	G–18½	231	9.24
50	30–34	mazda "B"	S–19	506	10.1
50	30–34	mazda "B"	G–30	515	10.3
50	30–34	mazda "C"	PS–20	739	14.78
75	30–34	mazda "C"	PS–22	1,210	16.12

Intermediate Schedule

Watts	Volts	Lamp	Bulb	Lumens	Lumens per watt
15	60–65	mazda "B"	S–17	137	9.14
15	60–65	mazda "B"	G–18½	131	8.74
20	30–34	mazda "B"	S–17	195	9.75
20	30–34	mazda "B"	G–18½	185	9.25
25	60–65	mazda "B"	S–17	239	9.57
25	60–65	mazda "B"	G–18½	221	8.85
50	60–65	mazda "B"	S–19	506	10.1
50	60–65	mazda "B"	G–30	515	10.3
75	60–65	mazda "C"	PS–22	993	13.23
100	30–34	mazda "C"	PS–25	1,676	16.76
100	60–65	mazda "C"	PS–25	1,461	14.61

NOTE: For further information on lamps, see A. R. A. Standards and Recommended Practices as shown in the Appendix.

Meaning of the Word Lumen. The table shows the quantity of light generated by each lamp expressed in lumens. A lumen of light flux is the flux emitted in a unit solid angle by a point source

of one candle power—A. I. E. E. standardization rule 857. That is, a lumen has been agreed upon as that quantity of light flux which is radiated in a unit solid angle from a one candle true point source.

A unit solid angle is the unit of solid angular measurement. It may be defined as that solid angle, subtended at the center of a sphere of unit radius by a unit area on the surface of the sphere. Also a unit solid angle may be defined as the solid angle subtended at the center of a sphere by an area on its surface, equal to the square of the radius. There are 12.57 unit solid angles

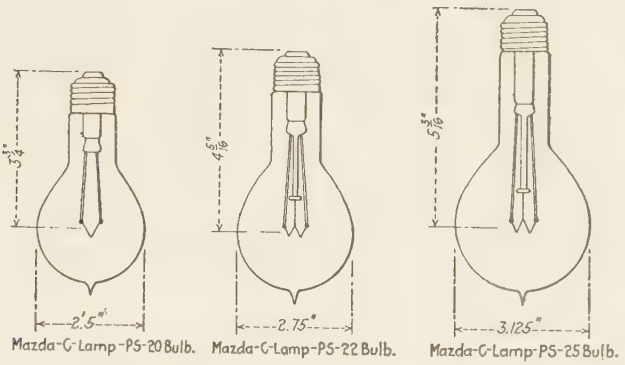


Fig. 109—Mazda "C" Train Lighting Lamps—Bulb Classification.

about any point in space; that is, any sphere contains 12.57 unit solid angles.

Electric Marker Lamps.—The importance of train marker lights makes it necessary that they be watched very closely by the train crew to see that they are kept burning. When oil lamps are used, a brakeman must remain on the rear car, and if this happens to be a business car, the occupants are constantly annoyed and interrupted by the brakeman walking back and forth through the car to observe the condition of the marker lamps. The use of electric marker lamps does away with this objectionable feature and has many other advantages. The wiring and operation of such lamps may be understood from a study of the diagram shown in Fig. 110.

Electric marker lights are connected to the lighting system of the car through a relay and small indicator lamps. If a marker

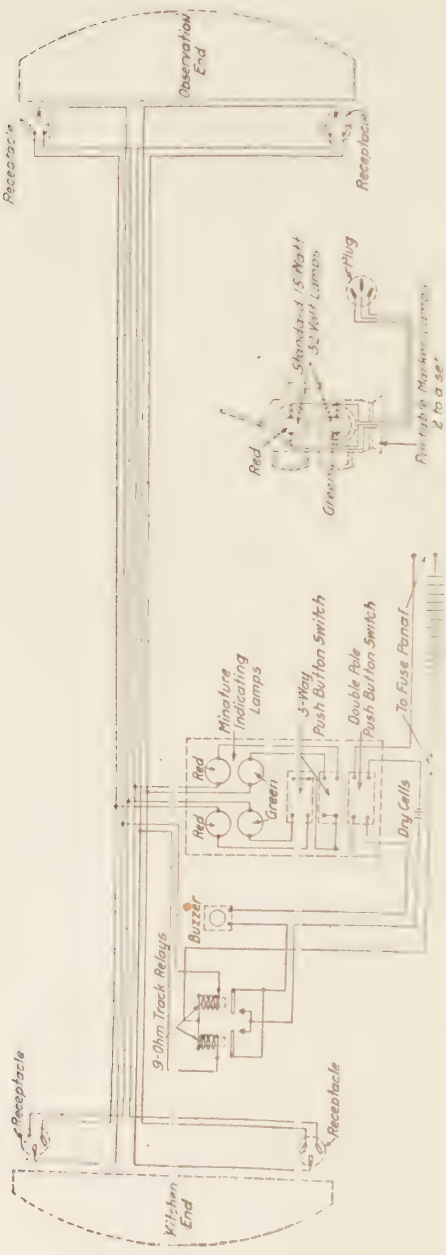


Fig. 110.—Wiring Diagram of Electric Marker Lamps as Applied to a Business Car.

lamp fails to burn at any time, the relay operates and rings a buzzer in the car, and the indicator lamp corresponding to the marker light which is not burning also ceases to burn.

The marker lamp itself has two compartments, an upper chamber with a red bull's-eye and a lower chamber with a green bull's-eye. Each chamber is equipped with a 15-watt 30-volt lamp in a porcelain-base marine receptacle. Connection is made from the light to the car by a 3-pole wall receptacle and plug.

There are two relays used, as shown on the diagram, one for each lamp. They are ordinary track circuit signal relays of 9

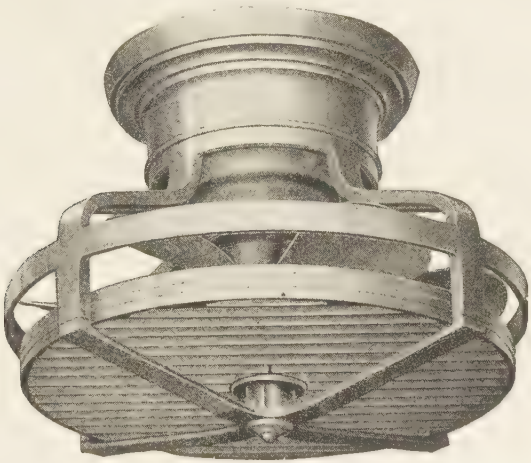


FIG. 111—"Safety" Ceiling Fan.

ohms resistance and operate an ordinary battery buzzer on a local line supplied by four dry cells. The indicating panel has four bull's-eyes, including a red and a green for each marker light—colors corresponding to the main lamps. Back of each bull's-eye on the indicator panel is a 4-volt, 2-candlepower lamp in a porcelain receptacle.

The controlling switches are located near the indicator panel; they include one 2-pole single-throw switch for the buzzer and light circuits; and two single-pole double-throw switches for changing the lights from green fo red or vice-versa.

With this arrangement, the brakeman can tell by the indicator lamp at the kitchen end of the car whether all marker lights are

burning, and if not, which one is giving trouble. He can also, by means of a switch, throw either lamp from red to green or from green to red as desired.

Electric Fans for Passenger Cars.—There are two types of fans in general use, the ceiling type and the bracket type. The ceiling type is mounted in a single row along the center line of the car. Bracket fans are mounted on the bulkhead, one at each end of the car, and direct the currents of air down the center of the car.

The Safety Ceiling Fan, Fig. 111, controls the direction and distributes the air blown from it. It consists of a motor, an air

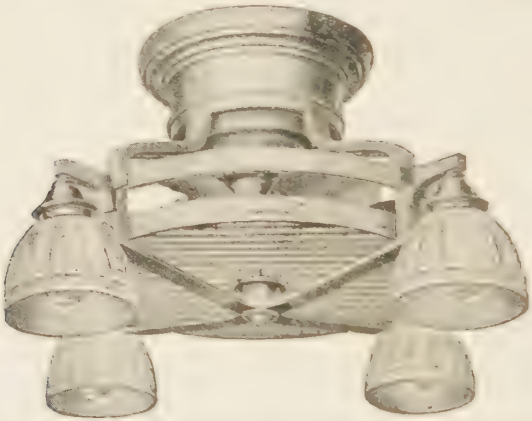


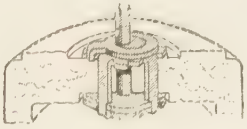
Fig. 112—"Safety" Ceiling Fan With Lamps Attached.

propeller, an air deflector or distributor, a supporting base and a frame or cage for proper assembly of the parts. The air deflector consists of a series of small parallel planes arranged in two sections within a circular band. These planes are so disposed at an angle to the air propeller as to direct the air movement into the form of a cone when the planes are rotated about the axis of the fan. The maximum velocity of the air is within a zone of 30 deg. to 45 deg. to the perpendicular and tapers off to zero directly beneath the fan and at 60 deg. to the perpendicular. The planes of the air deflector are arranged symmetrically each side of the axis so that when they rotate they produce a movement of the air at intervals of about twenty times a minute. This feature of intermittent breeze eliminates that steady gust of air common to

many types of electric fans. The current consumption of this fan is 75 watts. The Safety fans in some cars are also equipped with lighting fixtures, as shown in Fig. 112.

Switches and Cut Outs: Snap Switch. The snap switch is shown in Fig. 113. In this type of switch the blades are of the knife type and the contact jaws are of spring bronze. The switch is actuated by a spring. As the hard rubber handle is turned the spring tightens and the eccentric on the spindle forces the stop out through the cam point, where it is released just when the

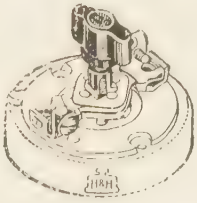
Contact Jaws on Porcelain Base



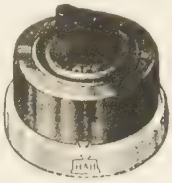
Section of Base Showing Eccentric Spindle

Hard Rubber Handle

Switch Blades and Indicator



Switch Complete Cover Removed



Switch Complete With Cover

FIG. 113—Parts of a Snap Switch.

spring is at proper tension to throw the blades. In this manner the blades are thrown to the "on" and "off" position, as desired. A disc indicator turns with the switch blades and shows the position of the switch through a small hole in the switch cover.

Single-Pole Snap Switch. A single-pole snap switch is connected in one side of a circuit and controls the circuit by opening and closing the one line.

Double-Pole Snap Switch. A double pole snap switch is connected in both sides of the circuit and controls the circuit by opening and closing both lines.

Three-Way Snap Switch. A three way snap switch has three points—a main and two auxiliary. The main point is thrown in

contact with one of the auxiliary points and then the other alternately. Three-way switches may be used in pairs, where, by the use of two three-way switches, a circuit may be controlled at two points.

Four-Way Switches. Four-way switches have four points of contact. One or more four-way switches in conjunction with two three-way switches may be used to control a circuit at as many points as desired.

Electrolier Switches.—Electrolier switches are used in many ways. By their use fans may be operated at various speeds, and

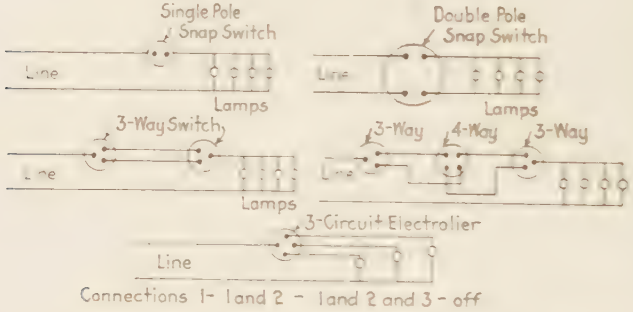


Fig. 114—Circuit Diagrams Involving Snap and Push Switches.

the individual lamps of a group may be controlled in various combinations by successive snaps of the switch. Circuit diagrams, in which all of these switches are used, are shown in Fig. 114.

Push Button Switches.—The push button switch is constructed on the same principle as the snap switch, having knife type switch blades and spring bronze contact jaws. The contacts are operated by a spring when the button is pressed; the button with the pearl center indicates current "on." Push switches are manufactured in the same types as described in the snap switch.

Knife Switches. A knife switch consists of a porcelain or slate base upon which is mounted the knife blades, spring contacts and terminals. The blades are equipped with an insulated handle for operating. Knife switches are used to control circuits which carry heavy currents. Fig. 115 shows single and double pole single throw switches, respectively. Double-throw knife switches are used for special applications, such as throwing a power or

lighting circuit from one source of current supply to another, etc.

Plug Cut-Outs.— Plug cut-outs are connected in the lighting

Single Pole Push Button Switch

Single Pole Push Button Switch

Single Pole Single Throw Knife Switch

Double Pole Single Throw Knife Switch

Plug Cut-out 2-Wire Branch

Plug Cut-out 2-Wire Double Branch

FIG. 115—Push Button and Knife Switches; Plug Cut-outs.

and fan circuits to protect them. They consist of a porcelain base with receptacles that carry plug fuses, and have suitable terminal posts.

CHAPTER XII

INSTALLING A NEW CAR LIGHTING EQUIPMENT

The installing of a new car lighting equipment is a grade of work that ranks high in importance and high efficiency in this work is a big factor in keeping down the maintenance cost during the life of the equipment. A small defect in the wiring of a car may be the cause of much further expense for power in taking the car out of service and placing it on a shop track, for labor in locating and correcting the defect, and for loss of revenue due to the car being out of service.

There are many different classes of cars and types of car lighting equipments on the various railroads today, but practically the same methods are used in installing each equipment.

The electrician installing a new car lighting equipment first receives a complete set of blue prints from the electrical engineer; these prints show the plan of the entire equipment. The material for the job is furnished by the store department and the placing of the car to be equipped is cared for by the transportation department. The car erecting shop is the most suitable place for this particular line of work, as it is equipped with the necessary facilities which usually are not to be had in the other shops. In the car erecting shop, the trucks are taken from under the car and the car is placed on heavy trestles. This gives the electrician an excellent opportunity to run conduit and do other necessary work under the car floor.

In most cases, the car lighting equipment is installed during the building of the car, but, for the benefit of the maintainer, who is compelled to renew and repair certain parts of a car lighting equipment after the car is built, the application of a new lighting Safety F 2 equipment to a completed steel baggage car will be described briefly.

The axle generator system is practically a straight storage sys-

tem with the addition of an axle generator and regulators, therefore a description of the application of the axle-generator equipment will cover both.

Material.—The plans having been received, the next step is to determine what material is needed, etc. The following is a list of material required for this installation:

1 axle generator.
1 axle generator regulator.
1 lamp regulator.
1 Sangamo control panel.
8 lighting fixtures (complete with boxes).
2 three-way snap switches.
1 four-way snap switch.
1 tension spring guide.
1 tension wheel.
1 fulcrum.
1 suspension link.
100 ft. ¾" conduit.
20 ft. 1" conduit.
40 ft. 1¼" conduit.
40 ft. 1½" conduit.
90 ft. No. 0 wire.
50 ft. No. 4 wire.
1 plug cut-out.
1 steel regulator cabinet.
1 suspension bracket.
1 generator shaft.
1 tension spring bracket.
1 tension rod.
1 tension nut.
1 tension spring.
25 ft. No. 8 wire.
326 ft. No. 12 wire.
2 battery fuse boxes (complete).
2 junction boxes.
2 junction box covers.
5 conduit supports.
3 switch condulets.
1 generator connector box.
2 Dossert connectors.
2 charging receptacles (complete).
Bolts, nuts, screws, solder, tape.

Placing the Car on Trestles.—The work of jacking the car, removing the trucks, and placing the car on trestles, as shown in

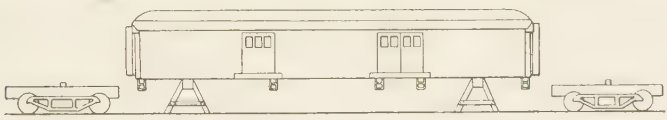


FIG. 116—Trucks Removed and Car Placed on Trestles for Application of Axle Equipment.

Fig. 116, is performed by the car erecting shop force. With the car on the trestles, the false bottom, which is made of galvanized iron, lined with asbestos, can easily be removed. This line of work is done under the direction of the tin shop.

Locating Battery Box and Cabinet.—Mark off the location of the battery box and regulator cabinet and have them installed. The location of the battery box, Fig. 117, is 8 ft. 2⅞ in. from the cross beam to the center of the battery box. The regulator cabinet, shown in Fig. 118, to be located in one corner of the car.

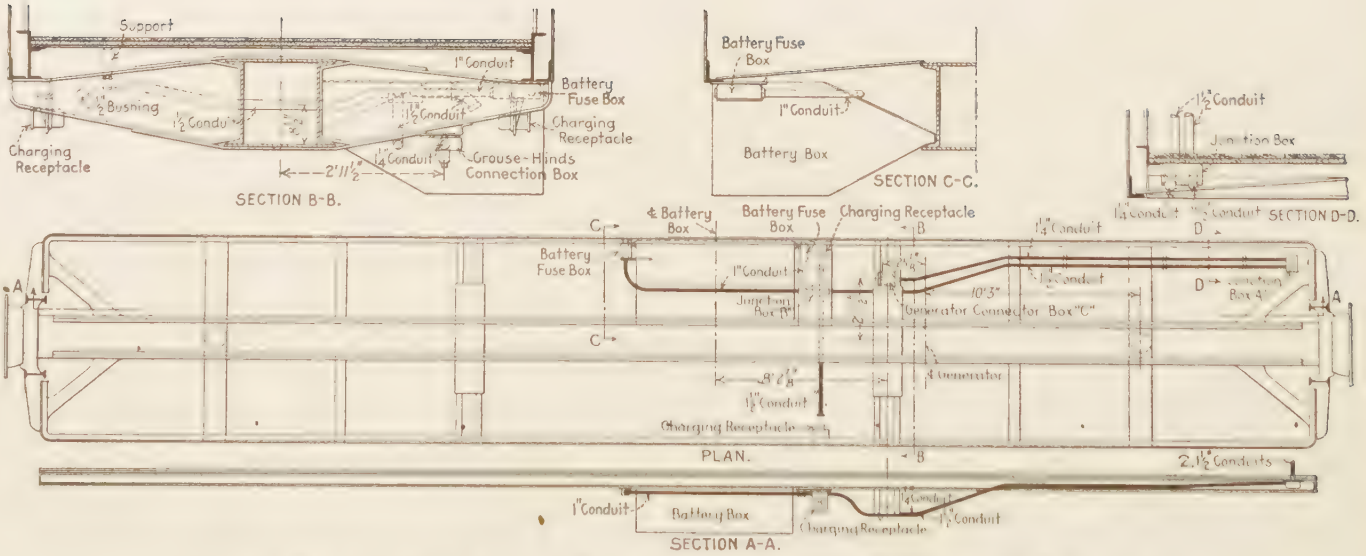


Fig. 117—Plan and Cross Sections Showing Arrangement of Conduit Under Floor of Car.

The regulator cabinet and battery box are made of sheet steel and their application comes under the direction of the cabinet shop.

Installing Conduit.—Mark off the location and then apply the various junction boxes that form the terminal points for the conduit. Located under the floor, Fig. 117, is a battery fuse box at each end of the battery box, two charging receptacles—one at each side of the car—junction boxes *A* and *B*, and generator connector box *C*. With these installed, the conduit is run as follows: a 1 in. line of conduit from the battery box to each battery fuse box and then to the junction box *B*; a 1½ in. line of conduit from each charging receptacle to the junction box *B* to the junction box *A*, and two lines from the junction box *A* to the regulator cabinet; a 1¼ in. line of conduit from the generator connector box *C* to the junction box *A*. The various conduit supports are then applied, completing the conduit work under the car.

The lighting fixtures, Fig. 118, are located along the center line of the car; a four-way switch is placed on the side near one of the sliding doors, and a three-way switch is placed at each end of the car to the right of the door. After the lighting fixtures are installed they are connected to the regulator cabinet by a line of ¾ in. conduit, also shown in Fig. 118.

In running the conduit care should be exercised not to flatten it when making the bends, and also to fasten it rigidly so that it will not rattle while the car is in operation which in time will damage the insulation on the wire. Holes through the steel structure of the car for the passage of conduit can be burned out in a few minutes with the oxy-acetylene flame.

Wiring.—The wiring diagrams, in Figs. 119 and 120, show that No. 0 wire is run from the battery and charging receptacles, through the 1½ in. conduit to the regulator cabinet, and that two No. 4 generator wires and one No. 8 field wire are run from the generator connector box through the 1¼ in. conduit to the regulator cabinet. The three No. 0 main battery wires are cut the proper length, then connected to a steel "fish" or pull wire and pulled from the junction box *B*, Fig. 117, to box *A*, and then to the regulator cabinet. The three ends hanging at box *B* are connected to the battery and charging receptacle terminals. The two No. 4 generator wires and the No. 8 field wire after being cut the

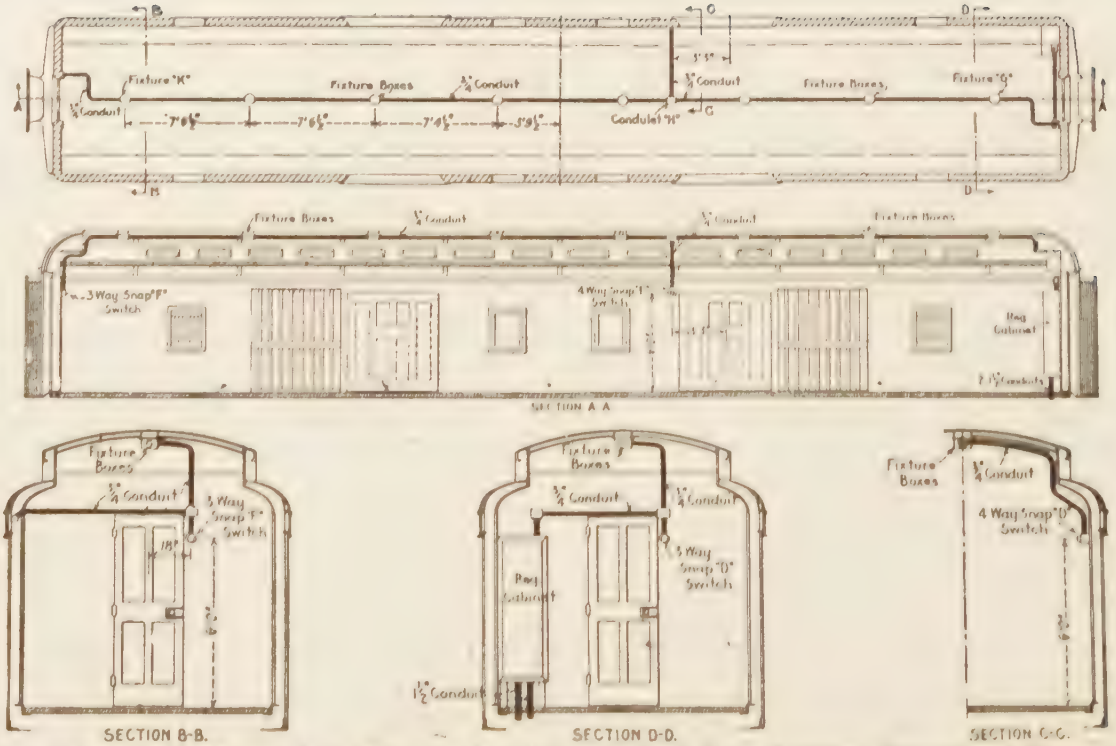


FIG. 118. Sectional Views of Car Showing Location of Conduit Runs, Switches, Fixtures and Cabinet

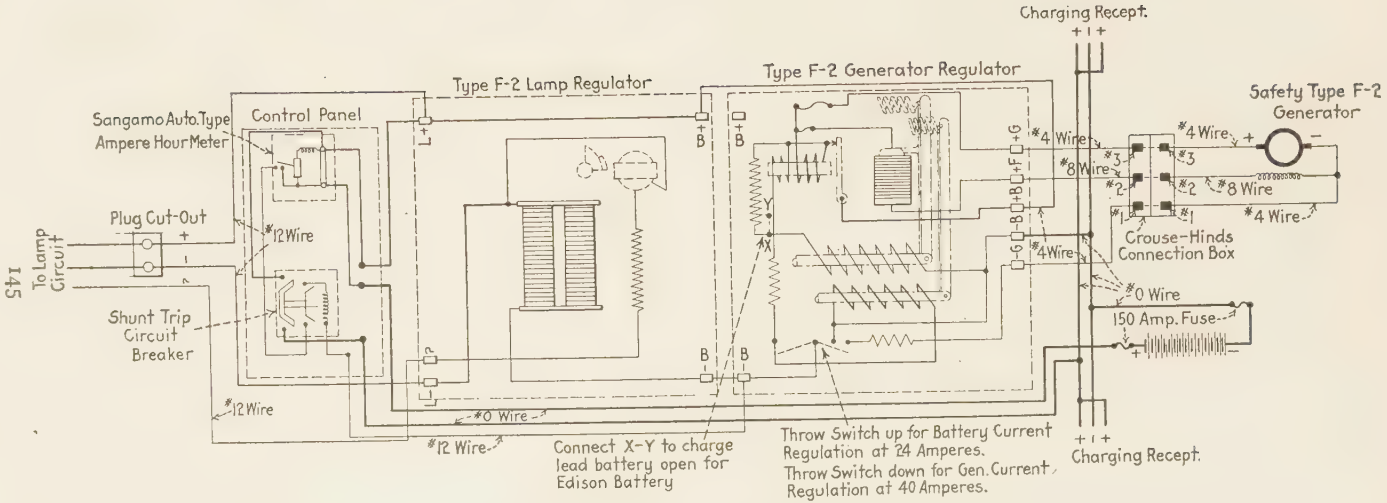


FIG. 119—Diagram Showing Circuit Arrangement of the Generator and Lamp Regulating Panels.

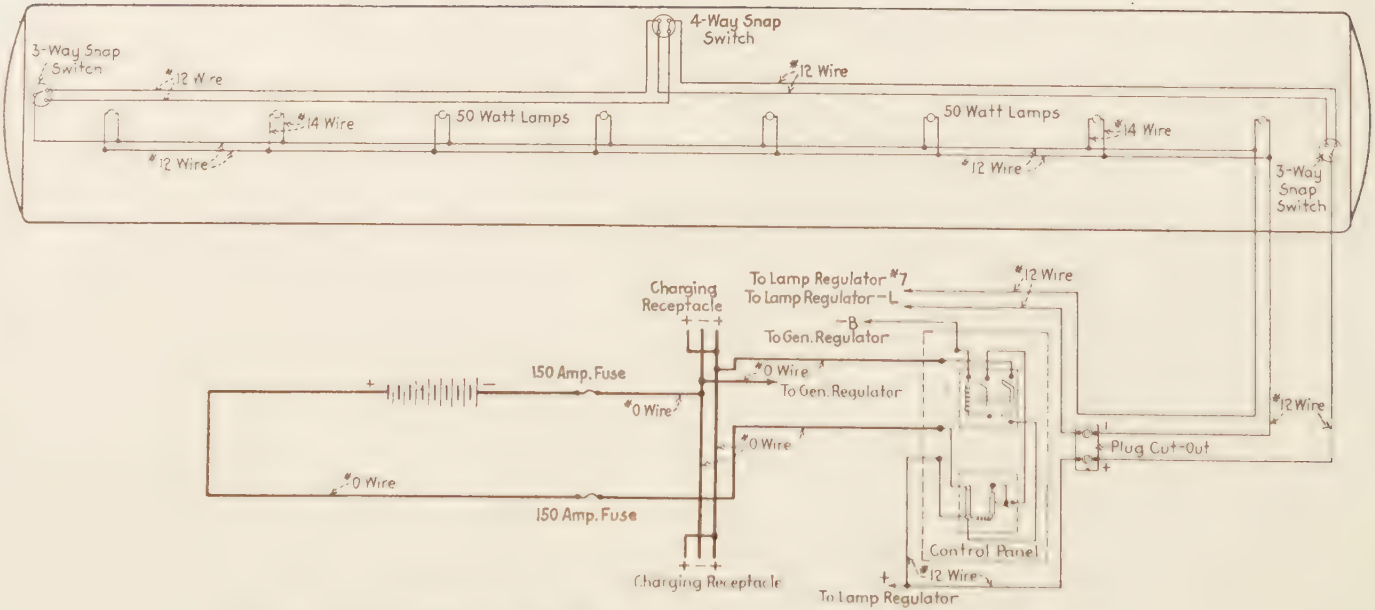


FIG. 120—Wiring Diagram of Car Showing Schematic Wiring of Regulator Panels.

proper length, are connected to a fish wire and pulled from the generator connector box *C* to the junction box *A*, and then to the regulator cabinet. The wiring diagram, Fig. 120, shows the size of the lighting circuit wires to be No. 12, and that, although all the lamps are connected to one circuit, four wires are used. The current to the circuit is fed from the branch block by two wires, but a third wire is required in connecting the switches for three-way and four-way control and a fourth wire is used to control the main lamp regulator coil circuit. In wiring the lighting circuit, the No. 12 wire is cut into six lengths, two of these long enough to reach from the three-way switch *D*, Fig. 118, to the four-way switch *E*, two, long enough to reach from the three-way switch *F* to the four-way switch *E*, and two wires, one long enough to reach from the regulator cabinet to the three-way switch *D*, and the other long enough to reach from the regulator cabinet to the fixture *G*. The six wires when cut are coiled in respective pairs and pulled into the conduit, starting at condulet *H*. Four wires are pulled through the conduit from the condulet *H* to fixture *K* and from condulet *H* to fixture *G*. The four ends of these wires left hanging at condulet *H* are pulled to the four-way switch *E* and the four ends hanging at fixture *G* are pulled, two to the regulator cabinet and two to the three-way switch *D*. In pulling these last four wires, a fifth wire should be pulled from the regulator cabinet to the outlet box located at the three-way switch *D*, making three wires in all running to the three-way switch *D*.

In pulling the wires through the conduit from one pull box to another, the use of powdered soapstone will be found helpful in preventing the wires from sticking to the conduit.

Installing Panels.—The installing of the control panel, generator regulator panel, lamp regulator panel, and plug cut-out in the regulator cabinet is next in order. First measure the distance between the studs and compare this with the distance between the holes in the slate panel before attempting to hang them, because if these studs are not correctly spaced, the panel corners are very easily broken in forcing the panels over the studs. Lead washers should be placed over the hanger studs and in back of the slate panels to form a cushion, and lock washers should be used in bolting the panels in place to prevent the nuts from becoming loose due to vibration when the car is on the road. In applying the plug cut-out a piece of sheet rubber or other insulating ma-

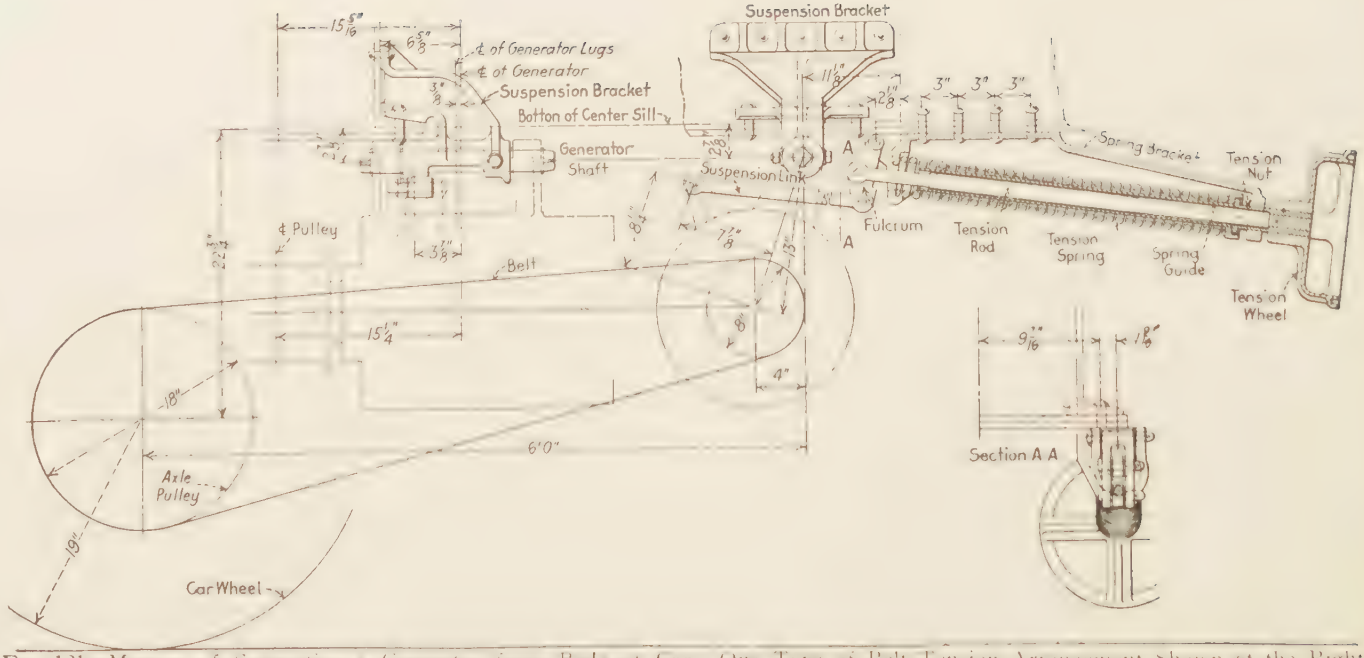


FIG. 121—Manner of Supporting a Generator from Body of Car. One Type of Belt Tension Arrangement Shown at the Right.

terial should be placed back of the cut-out between the porcelain base and the sheet steel locker. This rubber acts as a cushion as well as an insulator.

Under-Car Work.—The generator suspension bracket, belt tension device and axle pulley are next to be applied. The suspension bracket used is a triangular shaped steel casting and is riveted to the center sill. Fig. 121 shows the location of this bracket to be 6 ft. from the center of the axle to the center of the bracket. The truck is out from under the car when this casting is applied and it is therefore impossible to measure directly from the center of the axle to locate the bracket. This measurement is made by dividing the wheel base of the truck, which is, in this case, 8 ft.,

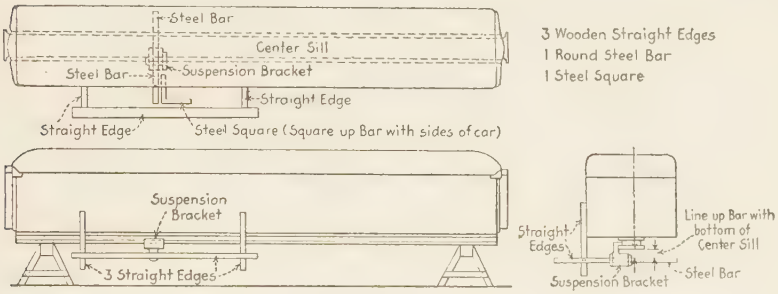


FIG. 122—Method of Lining Up Suspension Bracket With Side of Car and Bottom of Center Sill.

which will give 4 ft. as the distance from the truck center to the center of axle; adding 6 ft. will give a distance of 10 ft. from the truck center to the center of the suspension bracket. The truck center casting is fixed to the center sill and it is an easy matter to measure 10 ft. from the center casting and mark off the center line of the bracket. The bracket is temporarily bolted to the center sill, lined up and then riveted to the sill. The lining up is accomplished by means of a long bar having the same diameter as the generator shaft, three straight-edges, and a large steel square. The bar is placed in the suspension bracket, and squared with the straight-edges which are held against the side of the car as shown in Fig. 122. In this manner the bracket is lined up square with the bottom of the center sill and the sides of the car. It is very important that the bracket be in perfect alinement

because if it is not, the generator will hang crooked, and the belt will ride off the pulleys. After the spring bracket is riveted to the center sill, as shown in Fig. 121, the spring tension device is assembled. This device consists of a spring, spring guide, tension rod, tension nut, wheel, fulcrum, suspension link, and various connecting pins.

The placing of the spring into the bracket is a difficult job and a special device is necessary for this work. This device consists of a forged steel box with a screw for compressing the spring and a movable plate for pushing the spring out of the box into the bracket. The box, however, is jacked up against the bracket when the spring is being moved into the bracket, making it a very safe operation.

After the tension device is assembled the generator is suspended from the suspension bracket and connected through the suspension link to the spring tension device, as shown in Fig. 121.

The axle pulley and bushing are made of pressed steel and in two halves, four bolts being used to hold the bushing in place and the axle and likewise four bolts to hold the pulley in place on the bushing. The axle pulley and generator pulley should be in line and since the generator pulley is in the center of the center sill, the axle pulley should be located at the center of the axle in order that the belt may run true.

The battery is then placed in the battery box and the equipment is assembled ready for the wire connectors. In connecting the wires a magneto and voltmeter are used in selecting the wires at various outlets. All splices should be well soldered and taped. When the wiring is completed, the fuses should be applied and a final test made as follows:

Motor the generator from the battery in each direction. Test the polarity of the charging receptacles with a volt-meter. Test the entire system for grounds with a volt meter. Test the operation of the lamp regulator by placing the battery on charge and turning on and off the light circuits. Test the operation of the three-way and four way switches individually. The regulators are adjusted before leaving the factory and no further adjustment is necessary. The false bottom is then replaced, the trucks placed under the car and finally the belt applied. The car is then ready for service.

CHAPTER XIII

TESTING AND ADJUSTING CAR LIGHTING EQUIPMENT

The most important requirement in testing and adjusting a car lighting equipment is, to have the testing instruments correctly calibrated. In other words, all voltmeters, ammeters, hydrometers, thermometers, etc., should be checked with a standard before each test.

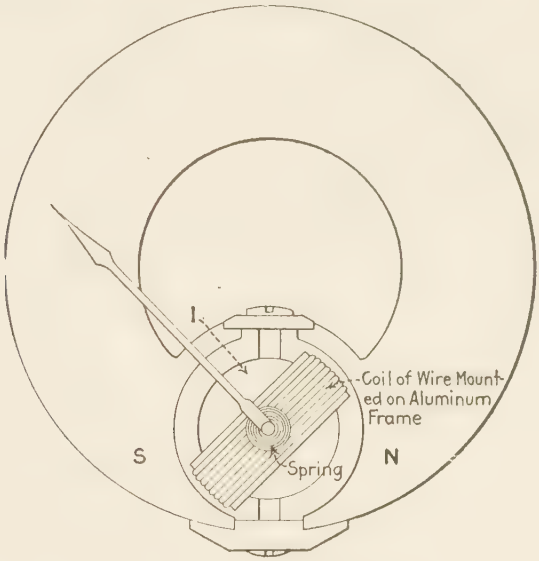


FIG. 123—The D'Arsonval or "Moving-Coil" Type of Instrument.

Each car lighting equipment consists of three main parts—the battery; the generator; and the regulators. The testing and adjusting of these main parts may be treated separately.

Battery Testing.—In testing a battery the operator must have the necessary knowledge to enable him to know from the various electrical and chemical indications whether or not the battery is

in a healthy condition. For example, an hydrometer reading of the electrolyte would not have any meaning whatever without the knowledge of the variation of the specific gravity on charge and discharge. Likewise, a temperature correction of the hydrometer reading could not be made, if the person testing the battery did not know the influence of temperature upon that particular solution. Therefore, in explaining the method of testing a battery, a few points will be included to indicate what correct battery performance is.

To thoroughly test a battery, it should be removed from the car and placed on a bench in a test room properly equipped for this particular work. When this is done, the battery should receive a cycle of charge and discharge, during which the following should be noted:

1. Height of solution.
2. Individual cell voltage.
3. Individual cell specific gravity reading.
4. Individual cell temperature readings.
5. Individual cell cadmium readings.
6. Rate of charging and discharging current.
7. Hours of charge and discharge.

Before running this test the following should be known:

1. The correct capacity of a battery of the type.
2. The correct variation of cell voltage of such a battery.
3. The correct variation cadmium reading of such a battery.
4. The correct variation of specific gravity of the electrolyte.
5. The normal charging and discharging rate of the particular type of battery.

For testing a lead storage battery, the following instruments are required: Voltmeter, ammeter, hydrometer syringe, thermometer, and cadmium test piece.

The voltmeter should be of the D'Arsonval double scale type, with scales preferably as follows:

High scale 0-150 volts, graduated to 1 volt per division.

Low scale 0-3 volts, graduated to .02 volt per division.

The ammeter should also be of the D'Arsonval type with scale graduated, 0-150 amperes, 1 ampere per division.

The hydrometer syringe should be graduated to read from

1.150 to 1.300 specific gravity, and the thermometer should read from 0 deg. F. to 120 deg. F.

For the benefit of those who are not familiar with the D'Arsonval type instrument, a brief description may be of interest. The D'Arsonval or "moving coil" type of instrument is more accurate than other types. At the same time it is more delicate and is more

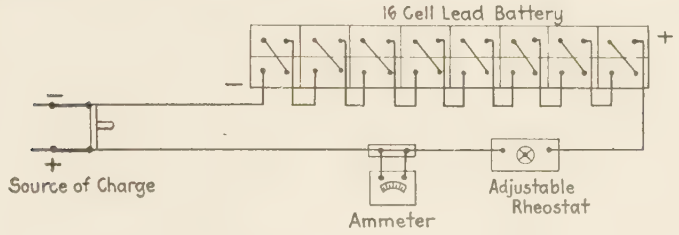


Fig. 124—Battery Connected for Charging.

difficult to manufacture. The principle of the instrument is shown in Fig. 123. Placed between the north and south pole of a magnet is a coil of wire mounted on a light aluminum frame. The coil is attached to the wire carrying the current to be measured through light springs, and when the current is sent through, one end of the coil becomes north and the other end south. Then according to

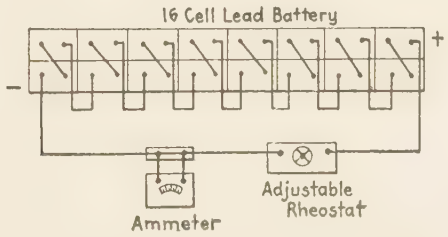


Fig. 125—Battery Connected for Discharge.

the magnetic law, the south end of the coil seeks the north pole of the magnet and the pointer attached to the frame passes across the scale. The "dead beating" or "damping" of this type of instrument depends on the strength of the magnetic lines of force—which is increased by the introduction of the iron core *I*, and careful grinding of the pole faces. Eddy currents are set up in

the aluminum frame which have a tendency to retard its movement and consequent deflection of the pointer. The D'Arsonval is perhaps the oldest type of electrical measuring instrument in use today. If carefully built, it is extremely accurate and dependable, although rather delicate.

In placing the battery on charge and discharge, it is connected in circuit as shown in Figs. 124 and 125. Note that on charge the positive side of the battery is connected to the positive side of the source of charge, and the negative side of the battery is connected to the negative side of the source of charge. In taking cell voltage readings, the voltmeter is connected across the terminals of the cell, while in taking cadmium readings one side of

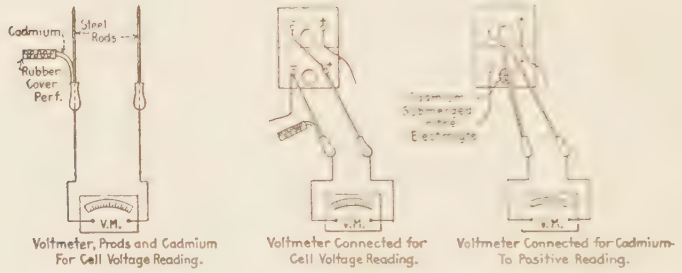


Fig. 126—Method of Taking Cell Voltage and Cadmium Readings.

the voltmeter is connected to one of the battery terminals and the other side of the cadmium test piece which is submerged in the electrolyte of the cell, Fig. 126. The specific gravity of the electrolyte at the end of charge should average 1.220; if necessary, the specific gravity of the electrolyte should be adjusted at the end of charge. During charge, the temperature should be watched very carefully and should not be allowed to exceed 110 deg. F. When the temperature approaches this point, the charge should be discontinued until the cells have cooled down. The cell voltage at the end of charge with normal charging current flowing should be 2.6 volts per cell. In making a test discharge, readings should be taken of the individual cell voltages every hour until one cell has dropped to 1.8 volts, and then at fifteen minute intervals until the voltage of the battery as a whole has dropped to an average of 1.8 volts per cell. Any cells which show less than

normal capacity and drop out considerably in advance of the balance of the cells should receive immediate attention.

The Cadmium Test Piece.—The cadmium test piece must be free from impurities and its surface should not be scraped bright; on the contrary, it should be aged, that is, covered with a layer of cadmium sulphate. Also, while using, the cadmium must not come in contact with any of the plates or connections, and the best way to prevent this is to cover the test piece with soft rubber tubing, this tubing to have numerous small perforations. When

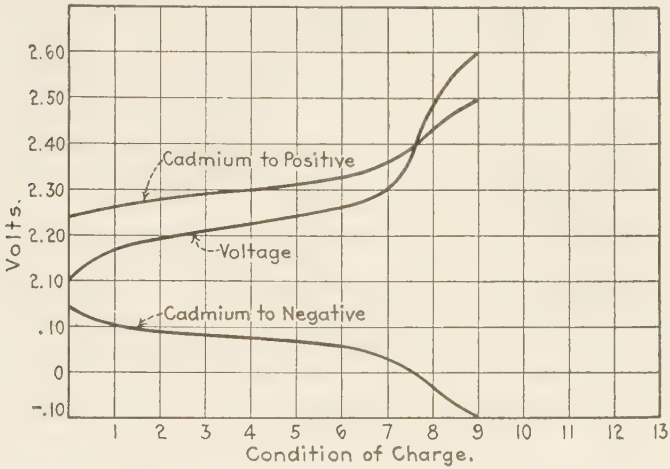


FIG. 127—Cell and Cadmium Voltage During Charge.

not in use the cadmium test piece should be kept immersed in dilute sulphuric acid, or at least immersed in such acid for a few hours before using. The reason for this is that there is a difference of potential between cadmium and cadmium sulphate and the bright surface sulphates so quickly that it would be necessary to scrape the test piece before each reading if comparable results were to be obtained. When a new battery is completely discharged, and normal current flowing, the test reading should be as follows:

Positive plate and cadmium, not lower than 1.98 volts; negative plate and cadmium, not higher than .18 shown by the voltmeter; and the voltage of the cell being the difference between these readings. When a new battery is completely charged and normal

charging current flowing the test readings should show as follows:

Positive plate and cadmium, about 2.45 volts; negative plate and cadmium, .14 and .16 volt, the cadmium being negative to the positive plate and the positive to the negative plate as shown by the voltmeter and the voltage of the cell being the sum of the readings. It will be noted that as a battery proceeds from a condition of discharge to charge that the cadmium is first negative to the negative plate and near the end of the charge becomes positive to the negative plate.

Figs. 127 and 128 show the conditions that obtain, Fig. 127 being that of charge and Fig. 128 being that of discharge, both

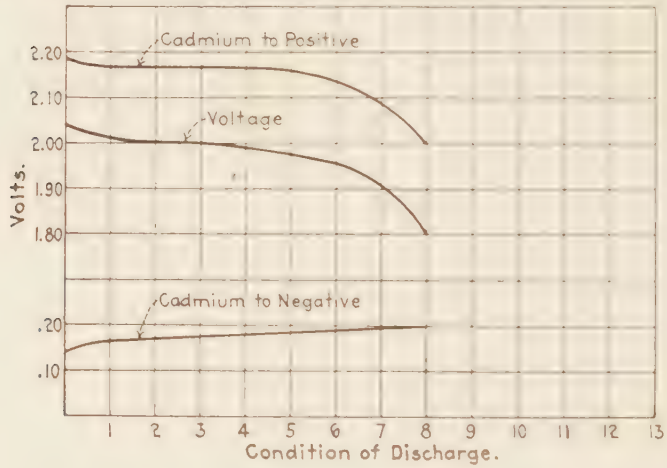


FIG. 128—Cell and Cadmium Voltage During Discharge.

being for a new battery at the eight-hour rate under normal conditions.

It will be noted that the sum or difference of the cadmium readings equals the cell difference of potential, as the case may be, though in practice it is somewhat difficult to measure these voltages sufficiently accurately to make these check exactly on account of the small deflection produced between the cadmium and the negative plate and variations in the location of the cadmium test piece at successive readings.

As the negative plates grow old they usually lose capacity, on account of the shrinkage of the active material closing up the

pores. To allow for this falling off in capacity the negative plates are usually manufactured with an initial capacity in excess of that actually required. An old negative plate is considered to have normal capacity when the cadmium reading at end of discharge has a value not exceeding .30 volt at the normal discharge. Note that on discharge and particularly at end of discharge, the lower the cadmium negative reading, and the higher the cadmium positive reading, the greater the capacity of the plate. An example will show how the cadmium readings are used to determine the condition of the plates.

Suppose that the voltage of the cell while being discharged at the eight-hour rate has dropped to 1.80 volts at the end of five hours and that the cadmium reading for the positive plates is 1.95 volts and for the negative plates .15 volt. In this case, the capacity of the negative plates is considerably in excess of the limit, while the positive plates are exhausted. This indicates either lack of active material on the positives or that all of the sulphate has not been converted into peroxide, that is, that the battery has not been fully charged. It is therefore advisable to make a second test, first making sure that the battery is fully charged. If the capacity remains the same and it is apparent that the plates are otherwise in good condition it will be necessary to renew the positive plates unless the capacity as obtained is sufficient for the requirements of the service.

If the cell voltage is 1.8 at the end of five hours and the cadmium reading for the positive plates 2.12 volts and for the negative plate .32 volt, it indicates that the positive plates are good and that the negative plates are lacking in capacity. In this case the negative plates, if of the Planté type, can be brought up to proper capacity by reversing them.

Bringing Negative Plates up to Capacity.—Negative plates, as they age, have a tendency to lose capacity, due to the shrinking of the active material, which, by closing up the pores, interferes with the diffusion of the electrolyte. The same effect occurs if there are impurities in the electrolyte which may act either to produce "local action" or clog the pores of the active material. To overcome these defects and again place the element in good condition, they are reversed in the following way:

Charge the battery fully and then remove the negative plates,

placing them in tanks filled with 1.240 specific gravity electrolyte, and connect them as anodes, that is, in a reverse manner to which they are normally connected. As cathodes, dummy plates of plain sheet lead about 1/16 in. thick can be used. The tanks should contain as much electrolyte as possible, as it must be as cool as practicable. The plates should be charged at double the normal eight-hour rate until they gas freely and the charging rate may then be gradually reduced to normal, and continued at the latter rate until the active material is thoroughly reversed and converted into lead peroxide, the sponge lead turning first to $PbSO_4$, then to PbO_2, as the action continues.

Toward the end of the reversal, the cells may be open circuited for a few minutes; then if on closing the circuit the plates immediately begin to gas, the reversal is complete. If gasing does not immediately take place, however, it is proof that the reversal is not complete and that only the surface of the crystals of the active material has been covered with a layer of lead peroxide, and that on open circuit the lead peroxide discharges into the metallic lead of the crystals underlying this layer. It requires a continued application of current to convert this sulphate again into lead peroxide. The plates having been completely peroxided, they are set up with new dummy plates and fresh acid and connected in the usual manner and current passed through them as before, the best value for the current in this case being the normal rate. When finally converted back into spongy lead and reassembled with the positives it will be found that the capacity of the negatives has materially increased.

New dummy plates and fresh acid are used so that any impurities thrown off will not be redeposited on the plates.

Electrolyte.- The electrolyte used with storage batteries of the lead type consists of dilute sulphuric acid, of a specific gravity of 1.200 to 1.300, depending on the amount of electrolyte and the construction of the battery. It should be free from all impurities such as hydrochloric, nitric or acetic acids, or such acid forming compounds, iron, arsenic, antimony, copper, mercury, or the slightest trace of platinum.

The specific gravity of the electrolyte used in standard car lighting batteries must be maintained between the limits of 1.215 and 1.225 with the battery in a fully charged condition. The

density of the electrolyte is dependent on the proportions of acid and water, or, in other words, upon the amount of the dilution of the acid. It is measured by means of an hydrometer. For variation of specific gravity on charge and discharge, see Fig. 129.

The density of the electrolyte has an important bearing on the operation of the battery. If it is too high, sulphating is accelerated and the plates depreciate more rapidly. The resistance of the electrolyte is at a minimum at about 1.235 specific gravity, rising if the gravity be either increased or decreased. The density is expressed in terms of specific gravity, that is, the ratio of the weight of the electrolyte to the weight of the same volume of water, or in terms of some arbitrary scale. In speaking of the specific gravity of electrolyte, it is usually referred to as a whole number, thus 1.215, 1.220, 1.225 specified gravity is spoken of as 1215, 1220, and 1225. As the temperature of the electrolyte influences its density, and the density in turn affects the resistance of the electrolyte and the capacity of the battery, the electrolyte should be corrected for temperature. The following table gives the proper specific gravity of the electrolyte for various temperatures, the readings being that of the electrolyte at end of charge:

Degree, Fahr.	Specific Gravity.
106	1.208
97	1.211
88	1.214
79	1.217
70 Normal	1.220 Normal
61	1.223
52	1.226
43	1.229
34	1.232
25	1.235
16	1.238
7	1.241

It will be noted that the correction is approximately 1 point for each three degrees F. difference from normal temperature which is taken at 70 degrees F.

Warm electrolyte should never be used in a cell as it accelerates the injurious effects produced by other causes, and shortens the life of the plates.

Correcting Specific Gravity. When testing the specific gravity of electrolyte with a view of correcting same the following method should be used: Fill the cell with distilled water to normal level,

and place on charge. When fully charged, test the temperature and specific gravity and add sufficient acid or distilled water as may be necessary to bring the specific gravity to 1.220, when corrected for temperature.

When the electrolyte is found to be impure, due to the presence of any metal other than lead or any acid other than sulphuric, it must be immediately drawn off and fresh electrolyte applied, and such other action taken as may be necessary.

When diluting the acid, the acid should always be poured slowly into the water, and not the water into the acid. The reason for this is that a chemical combination is formed, which liberates heat, thus raising the temperature of the electrolyte, and if the water is

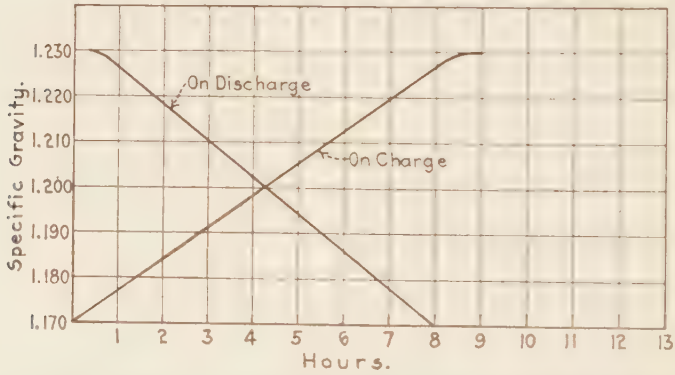


FIG. 129—Variation of Specific Gravity on Charge and Discharge.

poured into the acid the action is more rapid than if the acid be poured into the water, and the electrolyte is more liable to splash and burn the operator's person or clothes. The electrolyte must be allowed to cool before using; after cooling, the specific gravity will be found greater than when hot, but can be corrected to the proper density by the addition of a little distilled water. It is essential that the water used to dilute the acid or electrolyte should be free from all impurities and therefore only distilled water should be used for this purpose. Water obtained by condensing steam from a steam boiler should not be used, as it is liable to contain oil, or chemicals used in purifying the water for boiler purposes. The water should be obtained from a still and condensed in a block tin or lead pipe.

All corrosive actions of liquids on solid substances immersed

in them take place with the greatest rapidity at the surface of the liquid, and battery plates which project above the electrolyte deteriorate much more rapidly at this point that the submerged portion. This action can be rendered of small importance by keeping the plates always completely covered with electrolyte and making the lugs which pass from the plates to the terminals, of thick, dense lead. The normal level of the electrolyte is approximately 1 inch above the top of the plates.

Testing a Nickel-Iron Battery.—The instruments used for testing a lead battery are also used for testing the nickel-iron or Edison type, with the exception of the cadmium test piece, which is used only with the lead battery.

The nickel-iron battery is connected for charging and discharging in the same manner as shown for the lead type in Figs. 124 and 125.

The range of voltage of a nickel-iron cell during a normal seven-hour charge is from 1.6 volts per cell minimum to 1.8 volts maximum.

The range of voltage of a nickel-iron cell during a normal 5-hour discharge is from about 1.4 volts per cell maximum to 1 volt per cell minimum.

The electrolyte of a nickel-iron cell is a 21 per cent solution of potash, *KOH,* in distilled water with a small per cent of lithia having a normal specific gravity of 1.220 at 70 deg. F.

The specific gravity reading of the electrolyte of the nickel-iron cell should also be corrected for temperature. The correction for this solution is approximately 1 point for each 5 degrees F. difference from normal. The height of the solution in a nickel-iron cell varies with the different types of cells. The proper height for an A-8-H cell is 2¾ in. above the top of the plates, and for an A-4-H cell 3 in. above the top of the plates.

A check on the condition of the battery may be made upon each arrival at terminals by noting the ampere-hour reading and also by taking a voltage test of the battery with the lamps burning. This voltage test is practiced, not because it is the best indication of the battery as to state of charge, but because it is the only practical test that can be made without involving considerable expense and interference to the train movements.

Testing Axle Generators and Regulators.—A newly installed, as well as a periodically overhauled or repaired, axle generator

equipment should be tested and adjusted prior to being placed in service. As with the battery, none but correctly calibrated instruments should be used, and these instruments, consisting of a voltmeter, an ammeter, and a thermometer, should be tested with a standard before each test. If the regulators are conveniently located inside of the car, it is not difficult to make adjustments while the car is operating on the road, but even this flickering of light is annoying to the passengers and there are also other objectionable features. Where the regulators are located under the car body some other method of testing is required and a very

FIG. 130—Electric Truck Used for Carrying Generator to Test Room.

interesting problem is presented. Various schemes have been adopted, a few of which are:

1. Driving the generator by a portable motor mounted on a truck. The motor and generator connection being made by means of a flexible shaft which is connected to the generator armature shaft by removing the pulley.
2. Driving the generator by a motor located in a pit under the car. The drive consisting of a belt and two pulleys.
3. Removing the generator and regulators from the car to a test room, where the regulators are placed on a rack and the generator belted to a motor on a test block.

Method of Removing Generator from Car.—To remove a body-suspended generator from the car two planks are placed across the rails to the platform and a small truck is run up under the generator. The rocker bar is removed and the generator lowered on the truck; the truck is then hauled to the testing room.

In removing a truck suspended generator, the generator is rolled along two iron skids to the top of a table which is mounted upon two other skids. The generator and the table are moved along

the latter skids to the platform where the machine is blocked up and hauled to the test room on the rear of an electric truck as shown in Fig. 130.

Method of Testing. —The requirements for properly testing the apparatus are a fully equipped, well lighted and dust-proof, ventilated testing room with a three-conductor cable, well protected and of sufficient length to reach from the test room to the various shop tracks.

Fig. 131 shows the floor plan and Fig. 132 the wiring diagram for a suitable test room with the generator and motor centrally

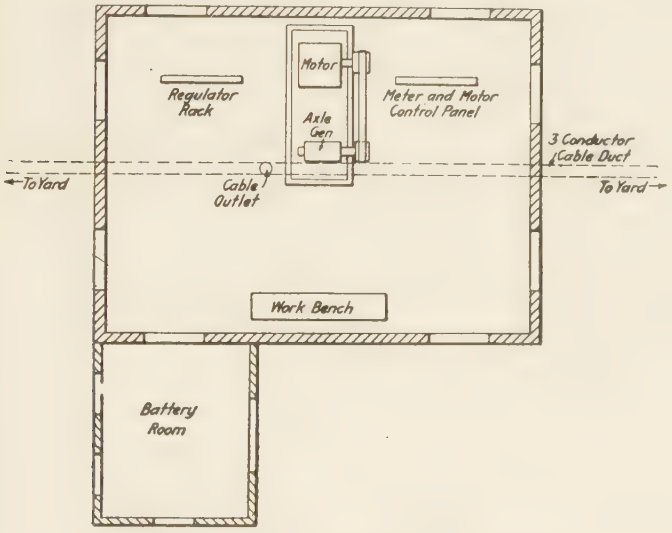


Fig. 131—Floor Plan of Generator Testing Room.

located, mounted together on a block. On the left, on a rack, is a lamp-bank, Sangamo control panel, lamp regulator, generator regulator and a three-pole double-throw switch. A motor control and meter panel, showing in the right hand part of Fig. 132, stands at the opposite side of the motor block and is equipped with five meters, Nos. 1, 2, 3, 4, 5, a circuit breaker, No. 6, a two-pole double-throw switch, No. 7, two 2-pole switches Nos. 8 and 9 and a starting box, No. 10. The functions of these instruments are as follows: Meter No. 1 records the battery current, No. 2 records the lamp current, No. 3 the generator current, No. 4 the

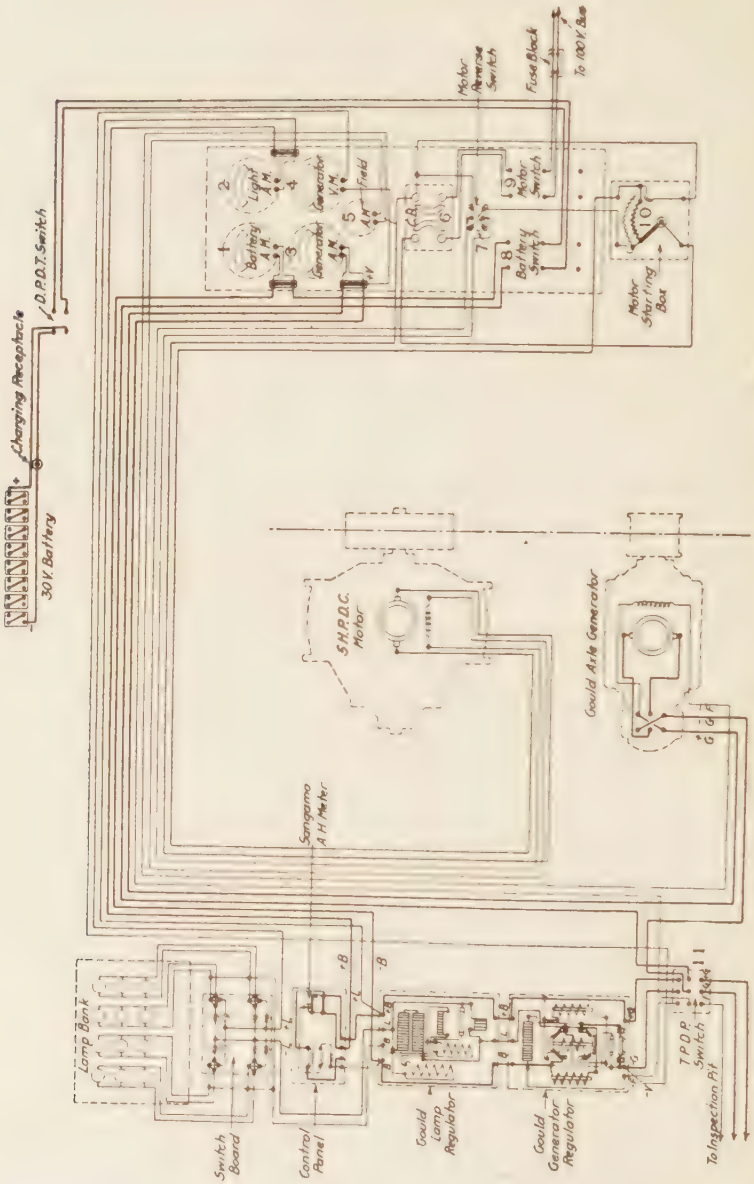


Fig. 132—Wiring Diagram of Generator Testing Room.

generator voltage, and meter No. 5 records the generator field current. No. 6 is a circuit breaker, No. 9 a switch and starting box, No. 10 is a speed regulator for controlling the speed of the motor; No. 7 is a switch for reversing the direction of rotation of the armature, and No. 8, a switch which controls the circuit to the battery in an adjoining room.

The three-pole double-throw switch, No. 11, at the bottom of the test rack is used to connect the test rack to the three-conductor cable or to the generator on the test block.

Method of Testing.—Assume that the test room is equipped with regulators and a spare generator in good condition, and the car is placed on the shop track for overhauling, testing and adjusting. The first step is to connect the spare generator on the test block with the regulator, battery and lamps on the car through the long three-conductor cable. After cleaning and overhauling the regulator parts, drive the generator taken from the car by the motor on the test block and note the following:

1. Commutation with rotation of armature in both directions.
2. Activity of pole changer, upon change of direction of rotation.
3. Temperature of bearings, coils, etc.
4. Generator current—light on.
5. Generator current—light off.
6. Operating current of series solenoid on generator regulator.
7. Generator voltage.
8. Automatic switch operating voltage.
9. Potential solenoid operating voltage.
10. Lamp voltage—generator operating.
11. Lamp voltage—generator not operating.
12. Freedom of movement of regulator parts; as dash pots, plungers, at various speeds of armature rotation.
13. Tests for grounds—using a voltmeter.

All voltage readings should be taken at the regulator panel on the car, because of the voltage drop in the long three-conductor cable. The wiring diagram in Fig. 133 and Fig. 134 show the proper points at which to make the various meter tests.

The automatic switch closing voltage and the generator voltage are measured at the same terminal. With the generator operating and meters connected, raise the generator voltage slowly by oper-

ating the field carbon pile by hand, and note the voltage at the instant the automatic switch closes. The voltage at which the potential solenoid operates is also measured at these terminals.

In making ground tests, connect the positive side of the voltmeter to the positive side of the circuit, and the negative side of the voltmeter to ground. A voltage reading will then indicate a negative ground. Interchange the meter leads, connecting the positive side of the voltmeter to ground and the negative side to

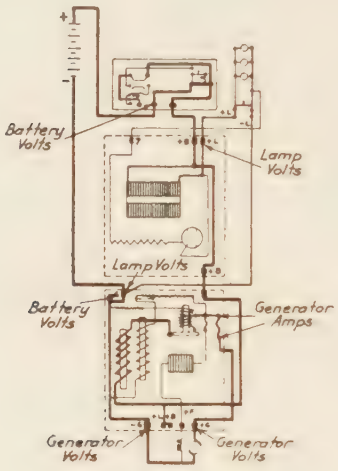


FIG. 133

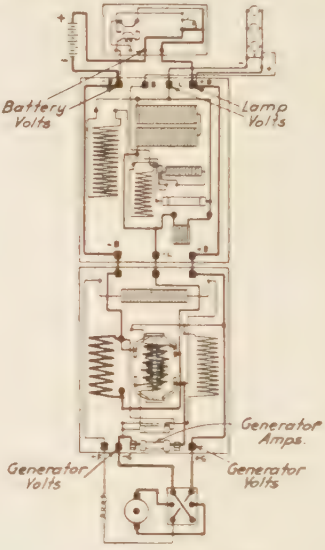


FIG. 134

FIG. 133—Wiring Diagram of Safety Axle Generator Equipment Showing Locations for Making Meter Tests.
FIG. 134—Wiring Diagram of Gould Axle Generator Equipment Showing Testing Points.

the negative side of the circuit. With these changed connections a reading will indicate a positive ground.

It is essential in making regulator tests to be familiar with the battery charging curve for that particular equipment, and also to allow the temperature of the coils to reach the operating point before attempting to make adjustments. See Fig. 135.

After the foregoing inspection and adjustments have been made, the next step is to place on the car the spare generator which is known to be in good condition, and then test connections

by driving the machine as a motor from the car battery; the car may then be released for service.

After a thorough overhauling, the generator that was removed from the car is tested on the block with the regulator on the test rack, through switch No. 11, and then held in readiness for use.

This method is a practical one in the case of a car showing signs of regulator trouble while operating on the road and when the

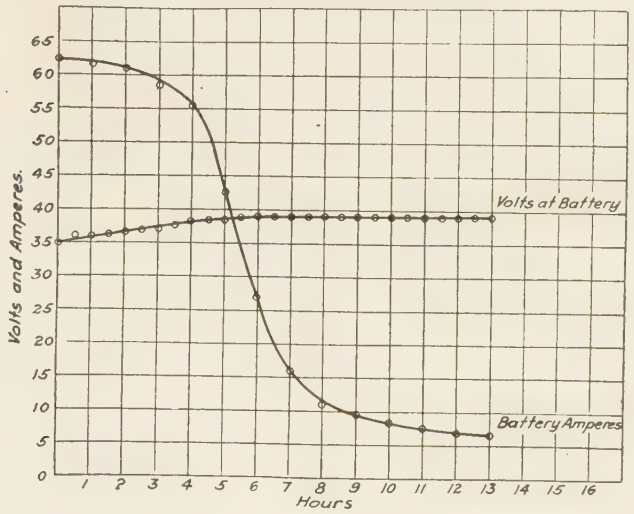


FIG. 135—Battery Charging Curve with Type "F" Dynamo Regulator.

trouble cannot be detected by the usual test. Instead of having a man ride the car on the road, have it placed in reach of the three-conductor cable and the regulator can be tested and the trouble located in a short time from the spare generator on the test block. In case of serious regulator trouble, the regulators can be interchanged with those on the test rack, repaired and held on the rack for testing purposes.

This method has proved better than most others for testing axle generators for three good reasons: the generator is not opened after leaving the test room, the regulators are not disturbed after adjustment, and the car is held out of service only a comparatively short time.

For road testing it is convenient to use a portable ammeter

with an external shunt, the external shunt to be fitted with fuse blades with the same center measurements as the generator fuse. To insert the ammeter in the generator circuit amounts simply to applying the shunt in place of the generator fuse. This scheme has the advantage that no wires are disconnected and therefore less time and space is required to make the test.

A record of each test should be kept in a record file and should have the following outline:

Car number	Generator output—lights off
System	Lamp generator set at
Place	Potential regulator set at
Date	Grounds
Workmen	Commutation—clockwise
Speed of armature	Commutation—counter clockwise
Automatic switch set to close at	Bearings
Generator output—lights on	Remarks

It is the practice on various railroads to inspect the car lighting equipment on each car upon arrival at the yards, but, to make a test of the battery generator and regulators, as described upon each arrival, would be impracticable. Therefore some means must be used to determine the condition of the equipment as near as possible without interfering with the operation of the train. One method of doing this is to note the temperature of the regulator coils upon arrival. If they are warm it is an indication that the generator has been operating; if they are cold the generator is not functioning properly. In the latter case, the generator is given the motoring test which consists of removing the belt from the pulley and operating the generator as a motor from the battery by closing the automatic switch by hand. The machine is started with full field and is brought up to maximum speed by increasing the field resistance with the carbon pile on the regulator panel. At maximum speed the field resistance is suddenly reduced to a minimum, and the automatic switch released. The momentum of the armature revolving in a strong magnetic field causes the automatic switch to close automatically, indicating that the machine is acting as a generator. This test will sometimes locate the trouble, but not always. If, however, the motoring test fails to show the source of trouble, then it is necessary to give the equipment a thorough test as previously described.

CHAPTER XIV

SERVICE INSPECTION AND TESTING

At large and congested railroad terminals it is not an easy matter for an electrician to persuade a train director to "drill" a car out of a regular run to permit electrical repairs. Usually, if the generator fails, the removal of the belt is suggested, or, in case of a total failure, that is, both generator and battery, the

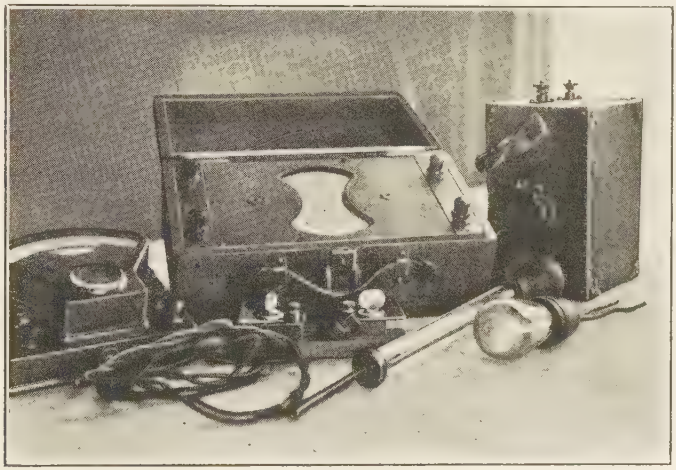


Fig. 136—Groups of Testing Instruments—Voltmeter, Ammeter, Magneto, Hydrometer and Test Lamp.

emergency candle lamps are pressed into service. This, no doubt, assists the train director to keep trains moving on time, but, on the other hand, it gives the car lighting department a lower percentage of efficiency.

For example, the efficiency of electric car lighting is figured on the proportion of the number of car arrivals with lights in good order compared with total car arrivals. If a car arrives at a ter-

minal with a defective car lighting equipment and is taken out of service and repaired, the failure list would only show one failure due to that particular defect, but if this same car is not taken out of service and repaired, until after it has made ten trips, then the failure list would show ten failures due to a single defect in this individual car lighting equipment.

Therefore the electrician at a terminal, in an effort to keep down the number of car lighting failures, must have some quick method of not only locating trouble, but also of making repairs.

Five instruments are used in testing a car lighting equipment—magneto, test lamp, voltmeter, ammeter, and hydrometer—these are shown in Fig. 136.

The cadmium test piece and thermometer used in testing battery capacity have been described and demonstrated in a previous article and will be omitted in this article to avoid confusion.

Most inspecting and testing is made with the car standing, when the generator is inoperative. In this position, the current to the lights is furnished by the storage battery. Upon the arrival of a car, the lighting circuits should be switched "on," thereby placing a discharge load on the battery; the individual lamps and fans in the various circuits throughout the car should then be inspected.

By the time this has been done, the battery voltage has had an opportunity to settle and a voltage reading across the two battery wires and the two lighting circuit wires at the switchboard can then be taken.

The battery voltage reading at this point for a 10-cell lead battery should be approximately 2 volts per cell or a total of 32 volts, and for a 25-cell Edison battery approximately 1.28 volts per cell or a total of 32 volts, when the battery is fully charged and with fair sized lamp load. The lamp voltage on cars equipped with a lamp regulator should read approximately 2 volts less than the battery voltage. If it is more the lamp regulator is out of adjustment—and should be adjusted by placing the battery on charge. The inspector then examines the generator regulator coils; if they are warm it is an indication that the generator has been operating; if the generator belt and pulleys are in proper order the car may then be considered as serviceable.

The yard electricians have more of an opportunity to inspect the equipment when the trains are backed into the yards for

cleaning, ice water, etc. A yard electrician receiving a car with a defective lighting equipment would first turn on all lighting switches and take a voltage test at the switchboard. If the battery voltage is satisfactory but the lamps do not burn, then the trouble is on the lighting circuits. On the other hand, if the battery voltage is low an individual cell voltage and hydrometer reading should be taken, the battery fuses examined and connections carefully inspected. If no defect is found in the battery, other than a discharged condition, the next step would be to place the battery on charge and then inspect the generator and regulators.

Motoring Test.—Trouble on a generator or regulator can usually be located by giving the generator what is known as the motoring test. This test consists of removing the belt from the pulley and operating the generator as a motor from the battery by closing the automatic switch by hand. The machine is started with full field and is brought up to the maximum speed by increasing the field resistance with the carbon pile on the regulator panel. At maximum speed the field resistance is suddenly reduced to a minimum and the automatic switch released. The momentum of the armature revolving in a strong magnetic field causes the automatic switch to close automatically, indicating that the machine is acting as a generator.

If the motoring test fails to show the source of trouble, then the two circuits, that is, the armature and field circuits should be tested individually.

The ground test of the entire system is taken by grounding first the positive and then the negative brushes of the generator to the generator frame with a small piece of wire while the lights are burning and the generator turning over as a motor. The motoring and ground test will sometimes, but not always, locate the trouble.

The armature and main generator circuit is connected in series with the battery circuit and may be traced through the regulator, generator, and connecting wires. A quick but crude way of testing this circuit is to remove the generator fuse, close the automatic switch and then flash the circuit by rapidly inserting and removing the generator fuse. An arc, upon removing this fuse, will indicate a closed circuit and vice versa. This operation will

blister the fuse clips, therefore it is well in making this test to have a small knife switch mounted on a set of fuse blades arranged in place of the generator fuse so that the switch blades take the arc instead of the fuse clips.

Upon inspecting an armature circuit for defects note the following: That the generator fuse is not blown; that all connections are tight; commutator clean; and brushes making good contact. If the commutator is rough and burned, it is usually due to either short brushes, dirty brushes sticking in the brush holders, or high mica between the commutator segments. Flat spots in the commutator are usually caused by open armature coils. Also be sure that the armature is not grounded by testing with the magneto from the commutator to the armature shaft or armature core.

The field circuit may be traced through the regulator, the generator and the connecting wires. This circuit includes the field carbon pile, field fuse, and field coils. A quick way of testing this circuit is to remove the generator fuse, close the automatic switch, and then remove the field fuse. If there is an arc at the fuse clips when the field fuse is removed, it will indicate a closed circuit and vice versa.

Upon inspecting a field circuit for defects the following should be noted: That the field fuse is not blown; that all connections are tight; that the field carbon discs are clean and that none are missing; that each field coil is producing a magnetic field of the correct polarity.

The last named may be ascertained by connecting, with the armature removed, and the field coils energized, the adjacent pole shoes with a piece of bar iron. Like poles will repel each other while unlike poles will attract, therefore, if the field coils are connected properly the adjacent poles will be unlike and there will be a strong attraction when connected through the iron test piece.

To locate a ground or open in a field or armature circuit, the circuits may be divided into two sections at the terminal block under the car. The three generator wires may be disconnected from the terminal block and the circuits tested to the terminal block with a voltmeter, and from the terminal block through the interior of the generator with a magneto. To make this test, disconnect the three generator wires at the terminal block under

the car, close the automatic switch and take a voltage test at the terminals across the field and generator wires, as shown in Figs. 137 and 138. A voltage reading at this point indicates that the armature and field circuits are closed through the generator regulator and connecting wires to the terminal block and vice versa.

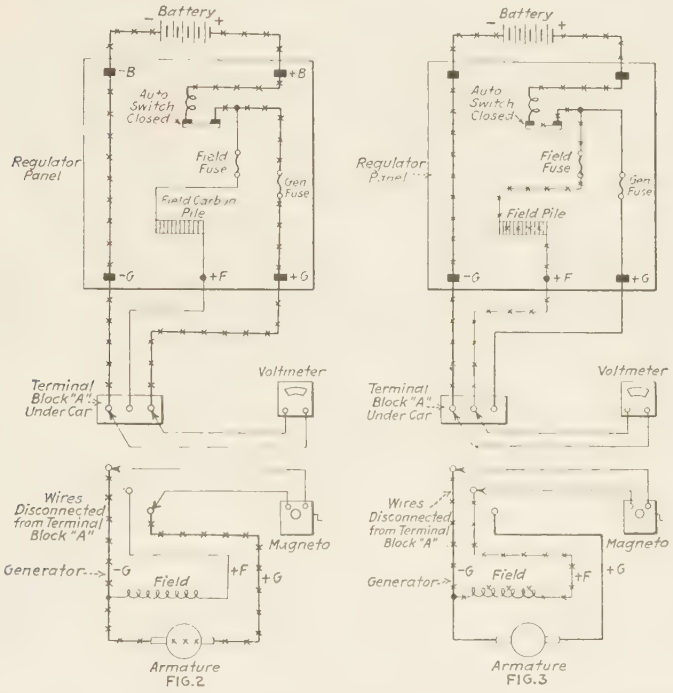


FIG. 137 (Fig. 2)—Testing Armature Circuit with Voltmeter and Magneto from Under Car.

FIG. 138 (Fig. 3)—Testing Field Circuit with Voltmeter and Magneto from Under Car. Circuits Through Which Magneto and Voltmeter Current Pass Are Marked with Crosses.

The field and armature circuits inside the generator may then be tested with a magneto across the three wires that are disconnected from the terminal block and lead into the generator. A ring of the magneto across the wires at this point will indicate a closed circuit and vice versa.

In locating trouble on a car lighting equipment, the lifting coil, the voltage regulating coil, and the lamp voltage regulating

coil circuits should be tested also. Each circuit includes a resistance unit in series with the coil and by energizing the circuit, which is accomplished by closing the automatic switch, turning on the lamps, etc., a closed circuit will be indicated by the heating of these respective resistance units.

A cell voltage reading frequently indicates a dead cell, but that does not always mean that such a cell is defective because the efficiency of the individual cells in a battery vary, that is, one cell will reach a state of full charge or discharge ahead of another, etc. Therefore, when an individual cell voltage reading of a lead battery shows five cells dead and the others read around 1.8 volts per cell, it would not necessarily mean that these five cells were defective. It may have been that this particular battery was permitted to remain in a discharged condition for some time and that these five cells were more heavily sulphated than the others, thereby requiring the additional charging to break down the sulphate. The proper thing to do in this case would be to place the battery on charge for a time and then take another cell voltage and hydrometer reading on discharge. If the cell voltage did not rise during the charge then there would be no doubt that the cells are defective and should be repaired.

Defective cells should be removed from the car to the battery repair room, the covers taken off and the elements removed from the tanks. The sediment should be washed out of the bottom of the tank; positive and negative plates washed; and separators and insulators should be renewed if found defective. The plates, if buckled, should be straightened and the cells reassembled. In an emergency a defective cell may be shunted out of circuit without having any serious effect other than lowering the voltage to the lamps when the car is standing and current is being supplied from the battery. This, however, should not be practiced when it is possible to change the crate.

A dry cell, that is, one from which the acid had leaked out through a small hole in the lead tank, would open the battery circuit. In this case, upon switching on the lighting circuits the lamps would not burn due to the circuit being open at the dry cell. The cell voltage reading in this case would be normal until the dry cell was reached and then a full voltage reading would be obtained because instead of placing the voltmeter across one

cell as intended, it would be across the opening in the battery circuit. It is therefore very important, when taking a cell voltage reading in an effort to locate a dry cell, that the voltmeter leads are connected to the high and not to the low scale of the voltmeter.

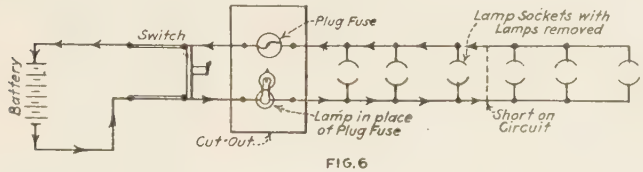


FIG. 6

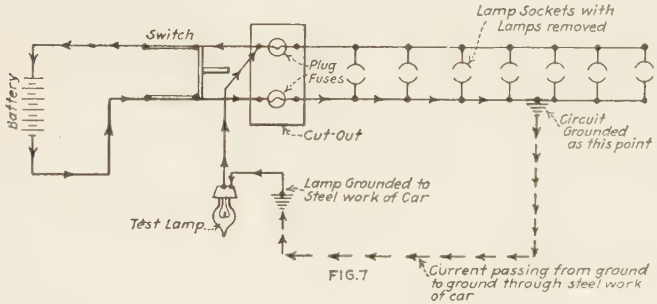


FIG. 7

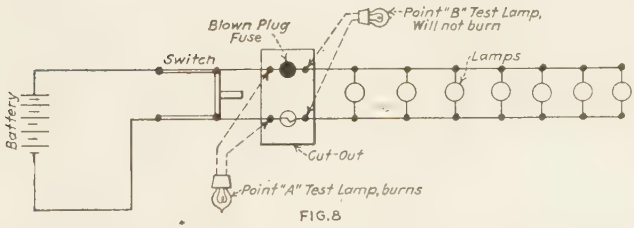


FIG. 8

FIG. 139 (Fig. 6)—Locating Short Circuit by Having a Lamp Burning Through the Short as an Indicator.
FIG. 140 (Fig. 7)—Locating Ground by Having Test Lamp Burning Through Ground as an Indicator. Path of Current Shown by Arrows.
FIG. 141 (Fig. 8)—Locating Open by Use of Test Lamp.

Should a battery have an open circuit due to a wire connector breaking off at a battery post, it may either be repaired in the battery house with the lead burning outfit or at the car with the burning arc which will be described further on in this article.

A cell voltage reading of an Edison battery would be taken in a

similar manner to that of the lead battery, but when a defective cell is found it is replaced by one from stock and forwarded to the Edison factory for repairs. The care of the Edison battery in the railroad battery repair room is limited to cleaning, painting, oiling, flushing, renewal of solution and charging. They are painted by the dipping process.

Testing for Grounds, Shorts and Opens. Trouble on a lighting circuit is usually a short circuit, a grounded circuit or open

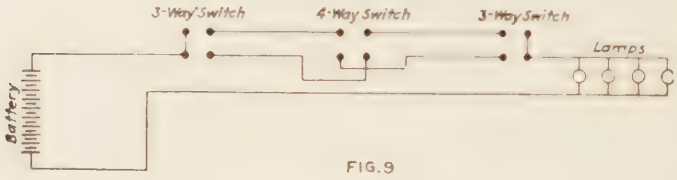


FIG. 9

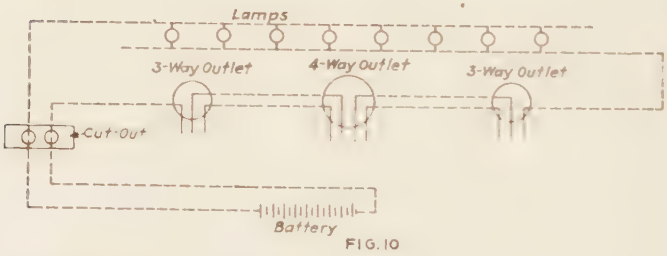


FIG. 10

FIG. 142 (Fig. 9)—Diagram of Three and Four Way Circuit.

FIG. 143 (Fig. 10)—Diagram of Three and Four Way Circuit Showing Lamps Overhead, Battery Under Car and Wires Protruding at Switch Outlets.

circuit. Various methods are employed to locate such defects and are as follows:

To locate a "short" on a lighting circuit:

First—Remove the lamp from each socket in the circuit.

Second—Screw a lamp in the branch block in place of the blown plug fuse.

Third—Turn the circuit switch to the "on" position and the lamp will burn by receiving the flow of current through the short in the circuit as shown in Fig. 139.

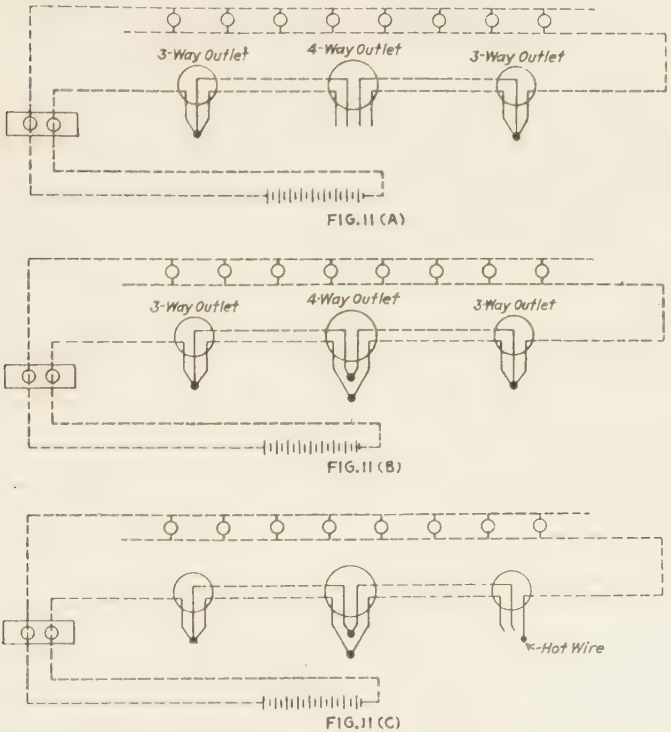
Fourth—Disconnect each fixture and branch of the circuit and

the lamp, by failing to burn, will be an indication that the short has been removed from the circuit.

A method of locating a "ground" on a lighting circuit is as follows:

First—Remove the lamp from each socket in the circuit.

Second—Connect a test lamp at the switchboard. Connect one side of the lamp to the side of the circuit that is not grounded



Part of Fig. 144—(Figs. 11(A) to 11(C).) See next page.

and ground the other side of the test lamp to the steel work of the car.

Third—Close the lighting circuit switch and the test lamp will burn by receiving the flow of current through the ground in the circuit as shown in Fig. 140.

Fourth—Disconnect each fixture or branch of the circuit, and

Continued from preceding page.

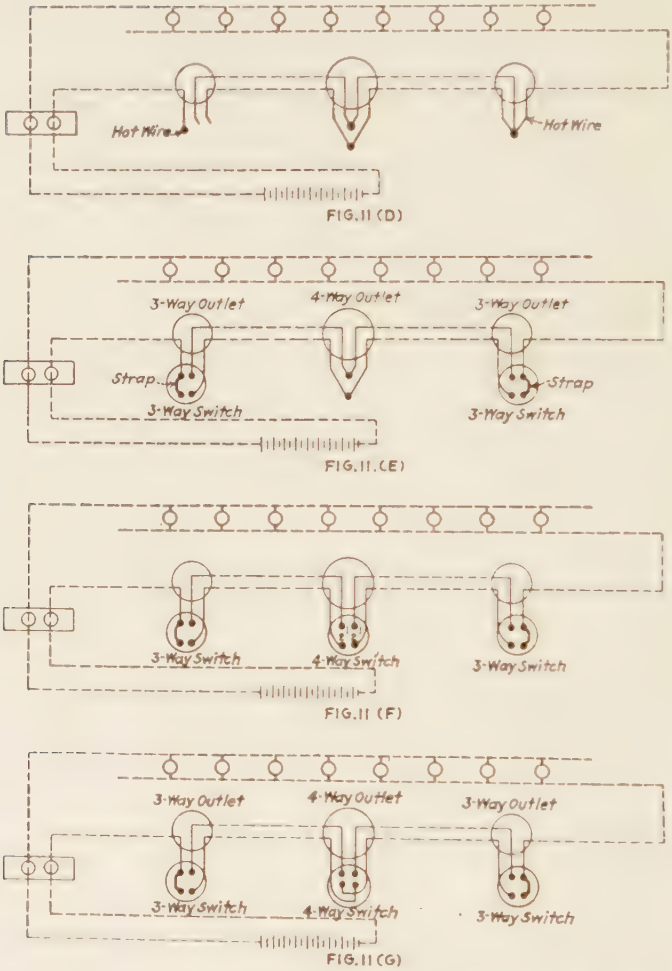


FIG. 144—(Figs. 11(A) to 11(G))—(A) Tie the Three Wires Together at Each Three-Way Switch. (B) Tie the Wires at the Four-Way Outlet in Two Pairs. (C) Pick Up Hot Wire at Three-Way Outlet. (D) Pick Up Hot Wire at Second Three-Way Outlet. (E) Connect Wires to Three-Way Switches, Connecting the Hot Wire to the Strap at Each Switch. (F) Connecting Wires to Four-Way Switch. (G) If Switches Do Not Operate Correctly, Reverse the Connections of One Pair of Wires at the Four-Way Switch.

when the grounded section is removed from the circuit, the test lamp will indicate same by failing to burn.

To locate an "open" in a lighting circuit test the circuit at various points throughout its entire length, starting at the switchboard with a test lamp.

The lamp burning when connected across the circuit at *A*, Fig. 141, will indicate that the circuit is closed to that point. If the lamp burns when connected at *A* and fails to burn when connected at *B* then the circuit is open at the cut-out, possibly a blown plug fuse or a broken wire. In like manner an open can be located at any point throughout the circuit.

Testing and Connecting a Three-Way and Four-Way Lighting Circuit.—The three-way and four-way circuit has been introduced in train lighting within the past few years and has been a stumbling block to many a car lighting man. The wiring scheme as shown in the diagram of a three-way and four-way circuit, Fig. 142, is easy to understand, but the difficulty is experienced in testing out and connecting the switches when the wires are concealed in the conduit with only the ends projecting at the switch outlet boxes, as shown in Fig. 143.

A method of procedure in connecting the switches to such a circuit is shown step by step in the diagrams *A, B, C, D, E, F, G*, Fig. 144.

Starting with all three switches disconnected, as shown in Fig. 143, proceed as follows:

First—Connect the three wires together at each three-way outlet as shown in diagram *A*, Fig. 144.

Second—Connect the four wires at the four-way outlet into two pairs, selecting the pairs that close the circuit and light the lamps, as shown in diagram *B*.

Third—Pick up the hot wire at one of the three-way outlets. The hot wire will be the one that will light the lamps when connected to either of the other two wires, as shown in diagram *C*.

Fourth—In like manner pick up the hot wire at the other three-way outlet, as shown in diagram *D*.

Fifth—Connect the two three-way switches, as shown in diagram *E*, connecting the hot wire to the strap of each switch.

Sixth—Mark the upper two connections on the four-way switch No. 1, and the lower two connections mark No. 2. Connect one

pair of wires to the connections No. 1 and the other to connections No. 2, as shown in diagram *F*.

Seventh. With the four-way switch connected, as shown in diagram *F*, it can be plainly seen that on one point of the four-way it would be impossible to close the circuit from either of the three-ways. This can be corrected by crossing one pair of wires, either pair No. 1, or pair No. 2, at the four-way, as shown in diagram *G*. The three-way and four-way switches will then be connected correctly. If by chance one pair of wires were crossed in the operation of the sixth step, then the seventh step would be unnecessary.

CHAPTER XV

TOOLS FOR HANDLING CAR LIGHTING EQUIPMENT

The conditions under which car lighting equipment must be handled when making repairs has led to the development of many special tools and methods for facilitating the work. In this chapter are described some of the tools used on some of the largest railroads for removing the parts from the car, in making the repairs, and in re-installing the parts on the car.

Tool for Removing and Applying Armature.—Removing and applying an armature to a generator under a car, without damaging the commutator, is a rather difficult job, therefore some tool

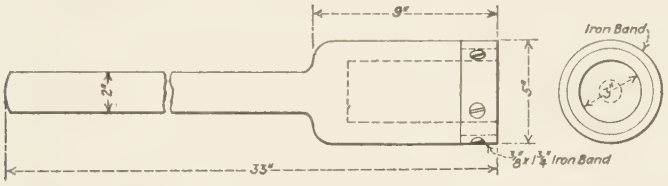


Fig. 145—"Wooden Leg" or Lifting Tool for Removing and Applying Armatures.

should be available with which the commutator end of the armature can be held steady as the armature passes in and out through the end of the housing.

A special lifting tool for this particular job is shown in Fig. 145 and is nicknamed "wooden leg" because of its resemblance to one. It is slipped over the commutator end of the armature shaft and is of sufficient length to allow for the passing of the armature through the end of the housing, with one lift.

Protecting Armature and Commutator While Handling.—Rough handling of armature which may result in rather expensive damage can easily be avoided. Instead of allowing one end of

the armature to rest on the corner of the commutator in the path of rolling bars, or other tools, while in transit or in the workshop, a truck or work bench should be equipped with some sort of carrier. Fig. 146 shows a block that may be used to support the armature on a truck and on the work bench. A canvas band may be used to protect the commutator from being scarred in handling; it can be quickly applied and removed.

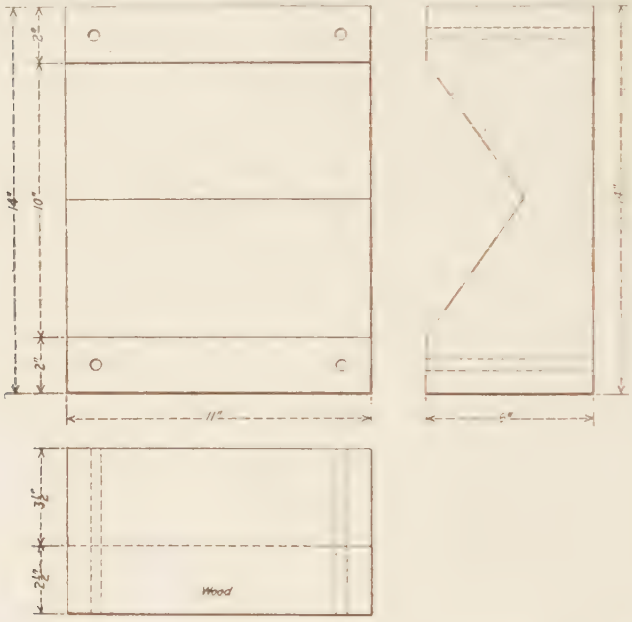


Fig. 146—Block for Supporting Armature on Truck and Work Bench.

Press for Removing Armature Shaft and Bearings. The pulley end-bearing is usually forced upon the armature shaft under pressure and the shaft forced in the armature in like manner. Therefore when it becomes necessary to remove the bearing from the shaft or to renew a shaft, some device is needed that will perform the work without damage to the armature, shaft or bearing. Figs. 147 and 148 show a hand press that will remove and apply these parts. It is constructed from two 2 in. x 16 in. x 16 in. steel plates, four 1½ in. x 48 in. steel rods, one 2 in. x 8½

in. screw with 4 in. square head, one 1 in. x 30 in. steel handle bar and eight 1¼ in. hexagonal nuts.

To remove a bearing from the shaft suspend the armature, with pulley end head complete, from head flange upon two wooden uprights, after removing the thrust washer from the armature shaft. Then by turning the 2 in. screw, Fig. 147, both the armature and shaft will be pressed in a downward direction

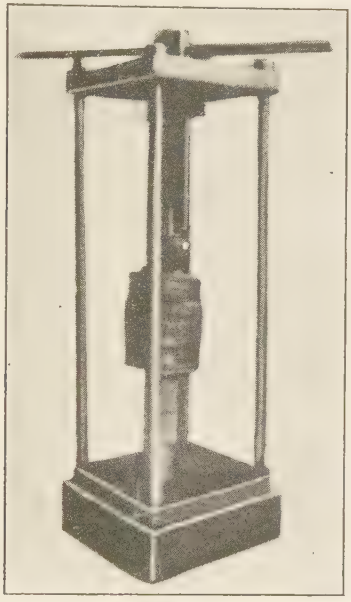


Fig. 147

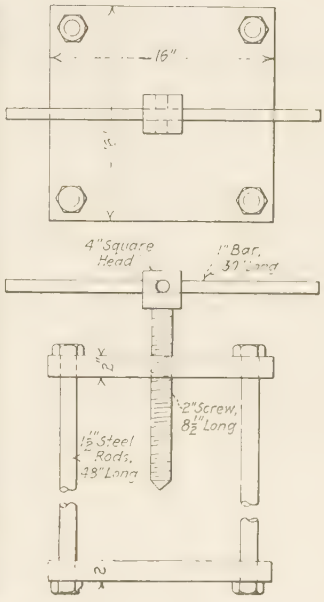


Fig. 148a

Figs. 147 and 148a—Armature Hand Press.

free from the head-end bearing. Care should be exercised to have the two uprights the same length, and the screw and armature shaft in perfect line before pressing off the bearing, otherwise there is danger of bending the armature shaft.

To remove armature shaft from the armature invert the armature in the press, as shown in Fig. 148c, resting core of armature upon sleeve. Then by removing the thrust washer and turning the screw the armature shaft will be pressed in a downward direction free from the armature.

The armature shaft and bearing can be replaced in like manner

by using sleeves that fit over the shaft. This method is a time saver and eliminates the danger of damage possible with the old method of driving the parts.

Applying and Removing Axle Generator Belts to Body Hung Generator. When an axle generator belt is found to be missing and it is within a few minutes of train time, there is no time to be spared if a car detention is to be avoided. If the generator is truck suspended, it can be easily pried forward with a bar

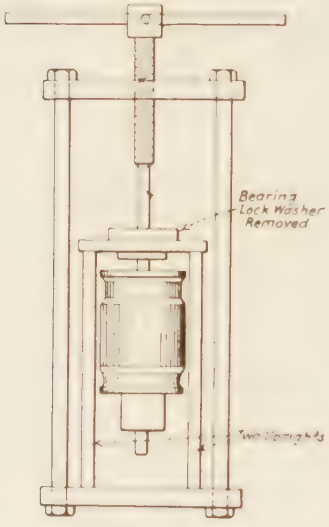


Fig. 148b

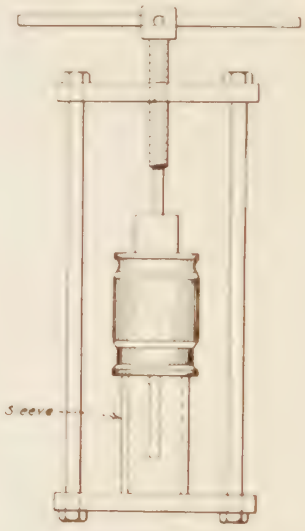


Fig. 148c

Fig. 148b—Pressing Pulley End Bearing Off the Shaft.
Fig. 148c—Pressing Shaft from Armature.

and a new belt applied. If, however, the generator is a body hung machine a train detention is apt to result, unless some device is at hand which can be easily applied to pull the generator forward and quickly put on a new belt.

Various types and makes of generators are now suspended from the car body, therefore such a device must be one that can be used universally. An arrangement of this type which recommends itself by its simplicity, consists of a bar and three chains as shown in Fig. 149. One of these chains is attached to the truck end rail and a second chain to the generator. The bar is then moved forward, as shown by the dotted line, which move

ment pulls the generator forward. The third or remaining chain comes into play when the generator has been pulled forward and serves to hold the machine while the belt is being applied.

This device is a great time and labor saver and may be used on any type of body hung generator. When equipped with this outfit one man can easily apply or remove a generator belt.

Pulley and Bearing Puller.—Armature pulleys, in addition to being tightly driven over the tapered armature shaft, at times also

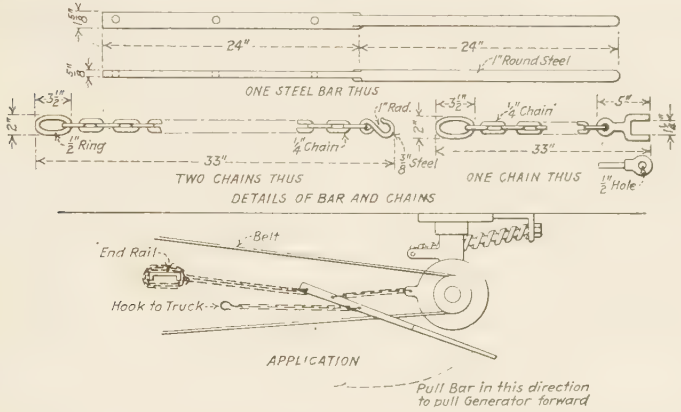


FIG. 149—Device for Removing and Applying Axle Generator Belts to Body-Hung Generators.

rust, making it a rather difficult job to remove them. The old method of removing them with a pinch bar, hammer and chisel was rather expensive because, in most cases, when the pulley was a tight fit the flanges were broken or the shaft bent.

A device for removing armature pulleys—shown in Fig. 150—consists of an iron base plate 1½ in. x 2 in. x 14 in., two ¾ in. bolts and a 1 in. x 12 in. machine screw. This same device with the addition of two plates ⅜ in. x 1½ in. x 7 in., fitted to the back bearing cap, as shown in Fig. 150, will act as a bearing puller.

Pulley Driving Iron.—The armature pulley is keyed to the armature shaft with a tapered fit. Therefore, if the pulley is not driven home when applied, it will gradually work loose and result in the key cutting away the shaft and bore of pulley.

The old method of driving the pulley home by hammering on the pulley flanges was possible when the generators were truck-suspended and had pulleys with straight flanges. But the new

body-hung machines are equipped with tapered flanged pulleys and to attempt to drive them in place by hammering on the tapered flange is sure to result in the fracture of the flange.

A driving iron, as shown in Fig. 151, is a valuable tool for

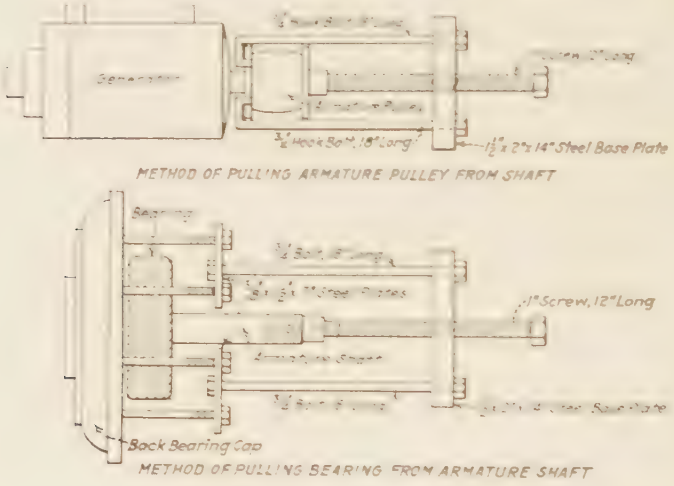

Generator
Hook Bolt, 18" Long
1½" x 2" x 14" Steel Base Plate
METHOD OF PULLING ARMATURE PULLEY FROM SHAFT
Bearing
Sock Bearing Cap
1" Screw, 12" Long
METHOD OF PULLING BEARING FROM ARMATURE SHAFT

Fig. 150—Pulley and Bearing Pulley.

this particular work. It fits over the nut on the pulley end of the shaft and delivers the shock of the hammer blow to the heavy web of the pulley.

Fig. 151—Armature Pulley Driving Iron.

This prevents the possibility of breaking the flanges and the fact that the blow is distributed evenly around the pulley bore eliminates the possibility of bending the armature shaft.

Lining-up Axle with Body-Suspended Generator.—To line up the axle pulley with a body-suspended generator, plumb from the bottom of the center sill to the center of the armature pulley,

as shown in Fig. 152, and note the relation of the center line of the pulley to the center line of the sill. If the center line of the armature pulley is 1 in. off the center line of the sill, then the axle pulley should be located 1 in. off the center of the axle. The relation of the center line of the pulley and the center line of the axle may be checked by measuring the distance *A* and *B*.

Press for Lead Battery Plates.—The press shown in Fig. 153, is designed for straightening buckled lead battery plates. It is

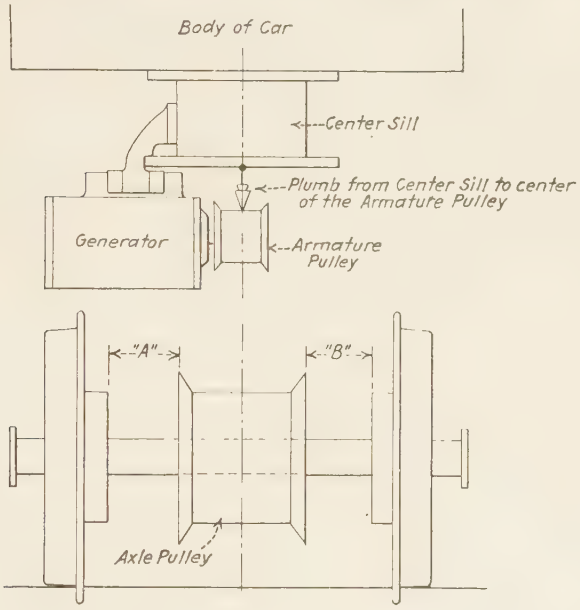


FIG. 152—Lining Up Axle Pulley With a Body Type Generator.

made from material which is not expensive and which can be found in nearly every railroad shop. The essential parts of the press are an air brake cylinder, an iron base plate and two iron jaws, mounted upon a bench. One jaw is fixed to the base plate, while the other jaw is connected to the end of the piston rod and slides over the base plate, guided by two projecting lugs. The air which operates the press is controlled by a valve located in the air pipe feeding line at one end of the cylinder. Wooden blocks are used as liners between the plates. The advantages of this press are the saving in time over ordinary methods and

the effect of the slow steady pressure applied to the plates, which forces them back to their original shape without the damage which results from hammering or other crude methods.

Wire Connectors for Car Lighting Batteries. Instead of skinning the ends of the wire and then tinning it, it is advantageous to tin the ends before removing the insulation. To make a car lighting battery lead take a piece of insulated wire of the proper length and dip the ends first into the soldering flux and then into a melting pot of solder as shown in Fig. 154. Allow it to cool and then remove the insulation.

This has several advantages over the old method. The heat of the solder loosens the rubber insulation from the wire and makes

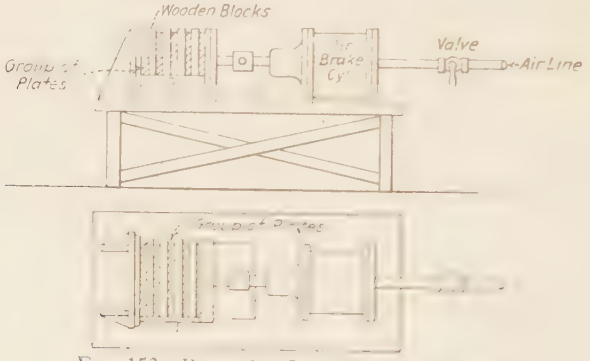


FIG. 153—Press for Lead Battery Plates.

it easy to remove and in case of flexible wire the strands are soldered together, making it impossible to separate them while removing the insulation.

Removing and Applying Battery Covers. Battery covers when applied are sealed with a compound to prevent the slopping of the acid. The compound is melted in a gas-heated pot, and when hot, is dipped from the heater and poured around the edge of the cover and allowed to cool. When it hardens it seals the space between the cover and the tank.

To remove the cover a steam cap is placed over the crate, as shown in Fig. 155. This cap measures 2 in. x 10 in. x 24 in., and is made of sheet iron. After a few minutes of steaming the compound softens and can easily be removed.

Emergency Welding.—Take a piece of No. 4 wire six feet long and attach a female Westinghouse battery hand connector

to one end, and a copper carbon holder to the other end. Then place a piece of stick carbon about four inches long in holder—see diagram *A*, Fig. 156. This combination can be used for repairing an open circuit in a battery when the wire is broken off close to the terminal of the battery.

This connector is a practical time saver in a case of emergency, such as when a car arriving at a terminal in a train in through

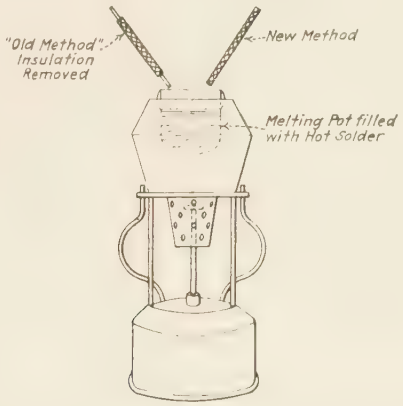


FIG. 154—Tinning Wire Connectors Before Removing the Insulation.

service and having only a ten-minute lay-over, with an open circuit in battery as described. Instead of cutting out the entire crate of cells and causing a four-volt drop in battery, the wire could be welded to battery terminal in a very few minutes, as follows:

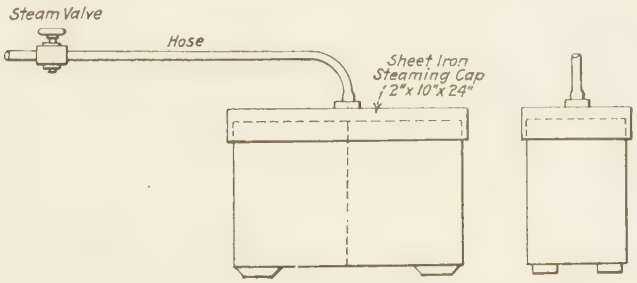


FIG. 155—Steam Caps for Removing Battery Covers.

Pull the crate with broken lead out on the battery box door far enough to reach the post to which the wire is to be attached, then place the connector to close the circuit of three adjoining crates, arranging so that the carbon point will close the circuit

through the post in which the lead is to be soldered. Then by drawing an arc between point of carbon and the post, the lead can be readily welded in place.

Lifting Irons for Edison Batteries.—When cleaning Edison batteries it is very important that the bottoms of the cans should be clean and dry, as well as the top and sides. By the use of the lifting irons shown in Fig. 157, the battery can be lifted by the crane and the bottoms well cleaned. Considerable time can

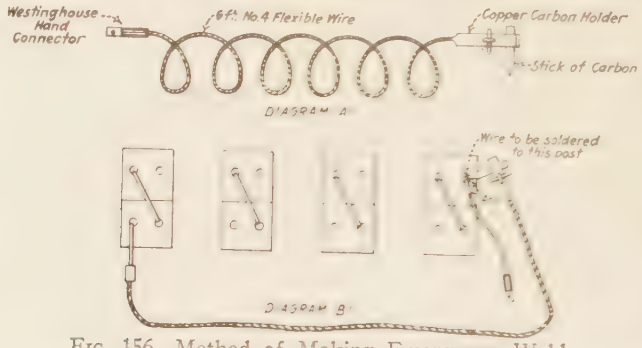


FIG. 156—Method of Making Emergency Weld.

also be saved by using these irons to move the batteries from the drip rack to the bench and from the bench to the truck.

The old method of sliding the crates when loading or unloading them from a truck, is undesirable as there is danger of breaking the skids or pulling the wire connectors out of shape. Small wire

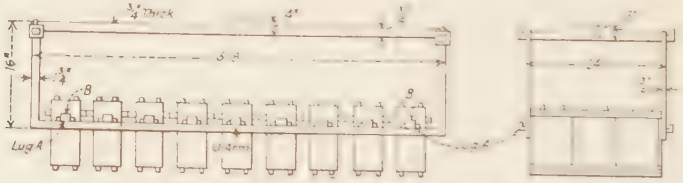


FIG. 157—Lifting Irons for Edison Battery.

hooks will hold the handles up and these irons can be readily placed under them; the details of the irons are shown in Fig. 157. Note that the lugs *A* on the U-irons slip into the end crate handles, as shown at *B*, thereby preventing shifting. The two long U irons are punched from $\frac{3}{8}$ in. boiler steel but the three top hangers are forgings. Another type of lifting iron is designed for carrying two crates of lead batteries.

CHAPTER XVI

E. S. B. CAR LIGHTING EQUIPMENT

The fundamental principle of the E. S. B. Axle System of car lighting is constant voltage, that is, the voltage of the generator or dynamo is held constant at a point just above the floating voltage of the battery. The dynamo, therefore, controls the voltage maintained at the battery terminals instead of the battery determining the dynamo voltage as in other types of axle equipments. It is also interesting to note that this equipment does not include a lamp regulator, and that the movable parts are confined to the automatic switch on the regulator panel and the armature within the generator.

The lamp regulator is eliminated by using 32-volt lamps, 15 cells of battery, and maintaining a voltage of approximately 33.5 volts at the switchboard.

The voltage at the lamps, is, therefore, so nearly normal that no further regulation is required.

The E. S. B. equipment consists of a generator, driven by a belt from the car axle, a generator regulator panel, which is mounted in a suitable cabinet inside of the car, and a storage battery, which is suspended in a box under the car body.

Generator.—The generator, Fig. 158, is constructed to obviate the necessity of dismantling the machine in order to renew any of the leads from the generator to the junction box on the car body.

The magnet frame is a solid steel casting with two internally projecting cylindrical pole cores. For the truck type machine, four feet are cast on the frame, and are solidly clamped to the suspension loop bars by means of two clamp bars. The body-suspension type machines are provided with two suspension lugs cast on the frame at the top and bored to receive a tubular steel bearing bushing through which passes a 1¾ in. steel bar supported

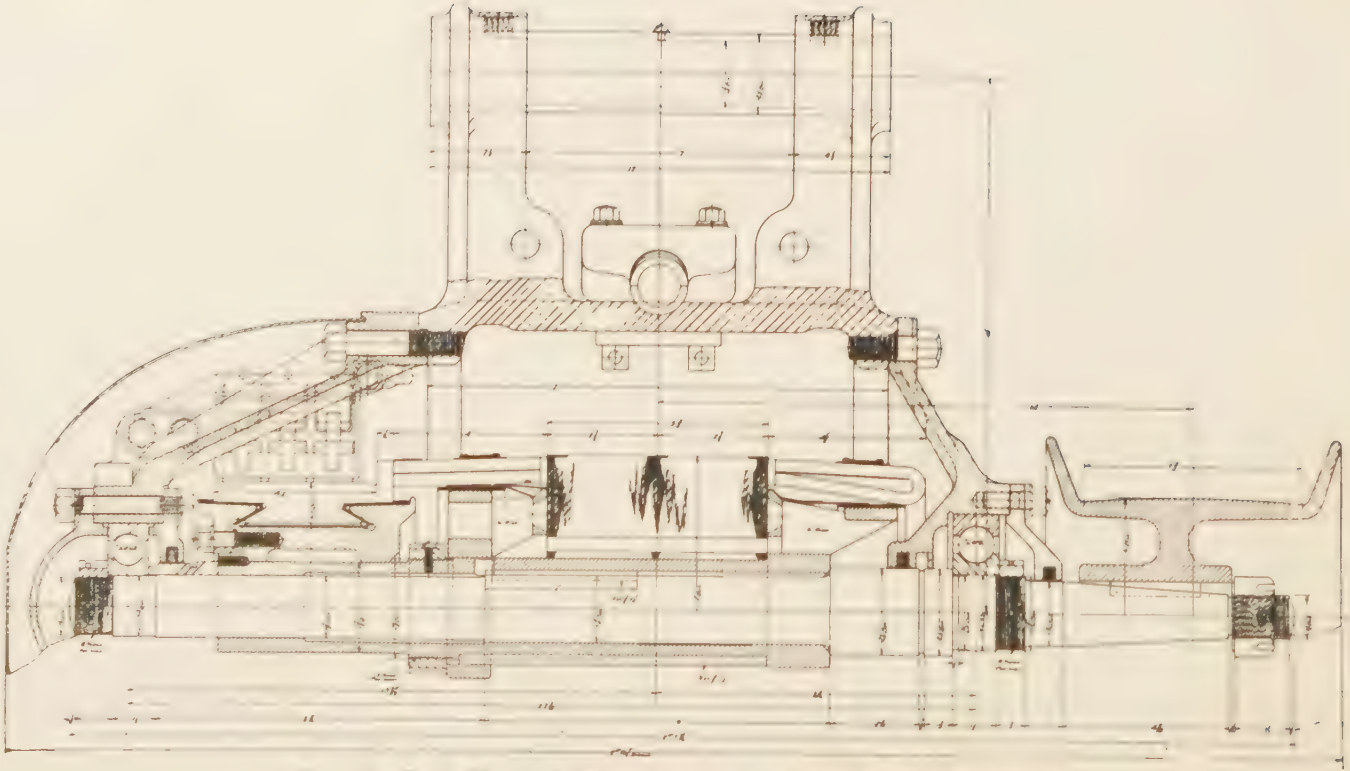


FIG. 158—Cross Section of Train Lighting Generator. Body Hung Type.

from the suspension carriage. Lubrication is provided by a grease cup mounted on the bushing, with suitable grease reservoir.

The bearing brackets on either end are substantial castings, that at the commutator end comprising four arms for supporting the ball bearing housing, between which ample spaces afford easy access to the brushes.

The pole shoes are of laminated iron riveted together and held in position by bolts passing through the pole cores. End laminations are spot welded for rigidity.

The field coils are solid impregnated and protected by heavy duck washers, while a steel spring plate between the coil and the

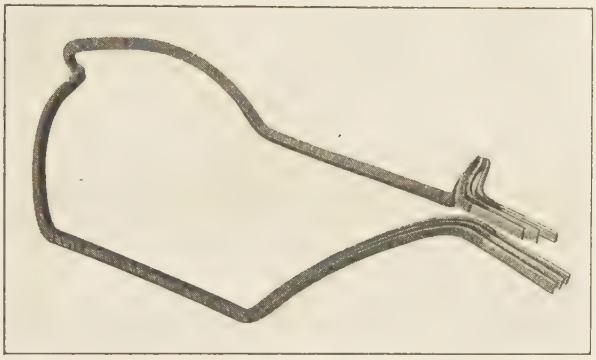


Fig. 159—Armature Coil, Insulated. Three Turns Are Taped Together in One Bundle.

frame prevents any motion or loosening and consequent chafing.

The armature and commutator are assembled on a separate quill. The armature is bipolar wound on a core formed of special non-aging high grade laminations, the outer ones spot welded. The coils, Fig. 159, are form wound, accurately shaped, and the leads securely sweated into the short solid risers of the commutator bars.

Commutator bars are of hard drawn copper, separated by best quality mica, undercut with rounded edges after assembly.

The brush holder yoke is in the form of a ring clamped over the ball bearing housing and the complete brush rigging with brush holders in place can be slipped off after disconnecting leads

and loosening the clamp bolt and set screw without dismantling any other part of the machine.

The brush holders are simple in construction, permitting easy inspection, and are designed to maintain strictly radial pressure on the brush with no tendency to rock and produce a different contact surface for each direction of rotation.

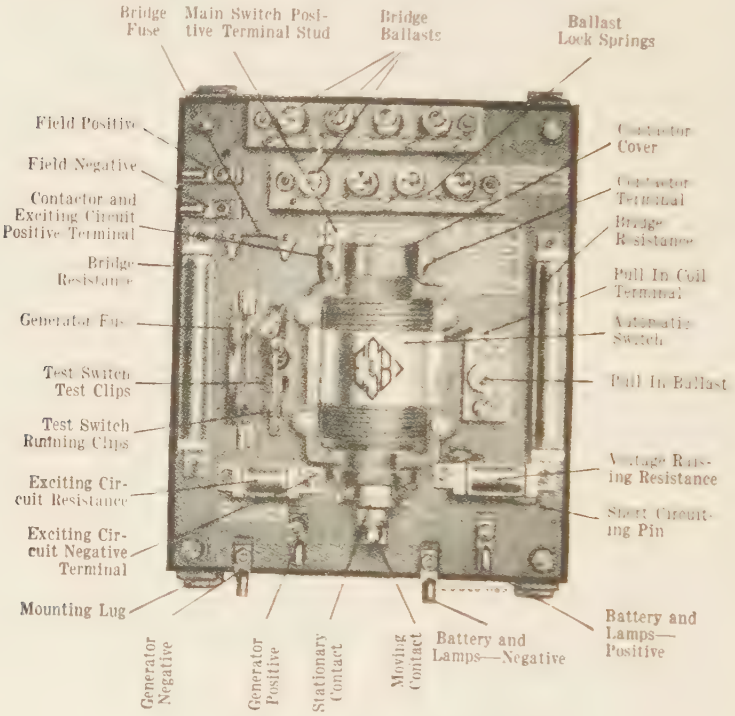


FIG. 160—Generator Regulator Panel.

The conductor for connecting the "short circuit" brushes is mounted on the brush holder ring, and a suitable fuse is inserted in this conductor.

A cover bell of pressed steel, held in place by two swivel bolts and heavy wing nuts, incloses the commutator end of the machine. Four terminals, two main terminals and two field terminals, are brought out through the frame of the machine into a terminal box, where detachable connections are made to the flexible con-

ductors passing through a suitable outlet in the tightly fitting terminal box cover, adapted for hose connection.

The box is reversible in the case of the body-hung generator so that the leads may be brought out from either side of the generator.

The following table gives the characteristics and principal dimensions and weights of the E. S. B. axle lighting generators:

	2 Kw. Truck Type	3 Kw. Truck Type	3 Kw. Body Hung
Continuous capacity	50 amps.	75 amps.	75 amps.
Overload capacity, 2 hrs.	65 amps.	100 amps.	100 amps.
Outside diameter, including feet	17 ins.	17 ins.	15¼ ins.
Length overall without pulley	33 5/16 ins.	34½ ins.	33⅞ ins.
Weight total without pulley	490 lbs.	510 lbs.	440 lbs.
Weight armature without ball bearing	155 lbs.	165 lbs.	150 lbs.
"Cut in" speed (with 15 cells) R. P. M.	300	425	475
"Full load" speed R. P. M.	490	625	650

Generator Regulator.—The generator regulator, Fig. 160, consists of a slate panel on which are mounted the resistances for the Wheatstone bridge control, a test switch, the automatic switch and the generator and field fuses. This panel measures 15 in. by 18 in. and weighs 75 lb.

The resistances for the Wheatstone bridge control consist of two fixed resistance units, one in each of two opposite branches of the bridge, and eight iron ballasts, four in each of the other two branches of the bridge.

The iron wire "ballast" resistance units consist of iron wire filaments enclosed in glass bulbs filled with hydrogen mounted on an elongated Edison base. These are secured in place in socket plates provided with steel spring locks which prevent the ballasts from becoming loose under vibration.

The test switch is a special spring-retained double throw type. The automatic switch is of the solenoid type consisting of a steel frame which supports three coils. Within these coils a cylindrical plunger with conical top is free to move vertically with minimum friction. This plunger carries, below, the moving contact, in the form of a laminated brush connected by a substantial flexible conductor to a terminal stud on the board. The fixed contact consists of a copper ring moulded into a support of high grade moulded insulation attached to the lower side of the switch frame. On top of the automatic switch a cylindrical projection of the switch frame surrounded by an exciting coil in series with the

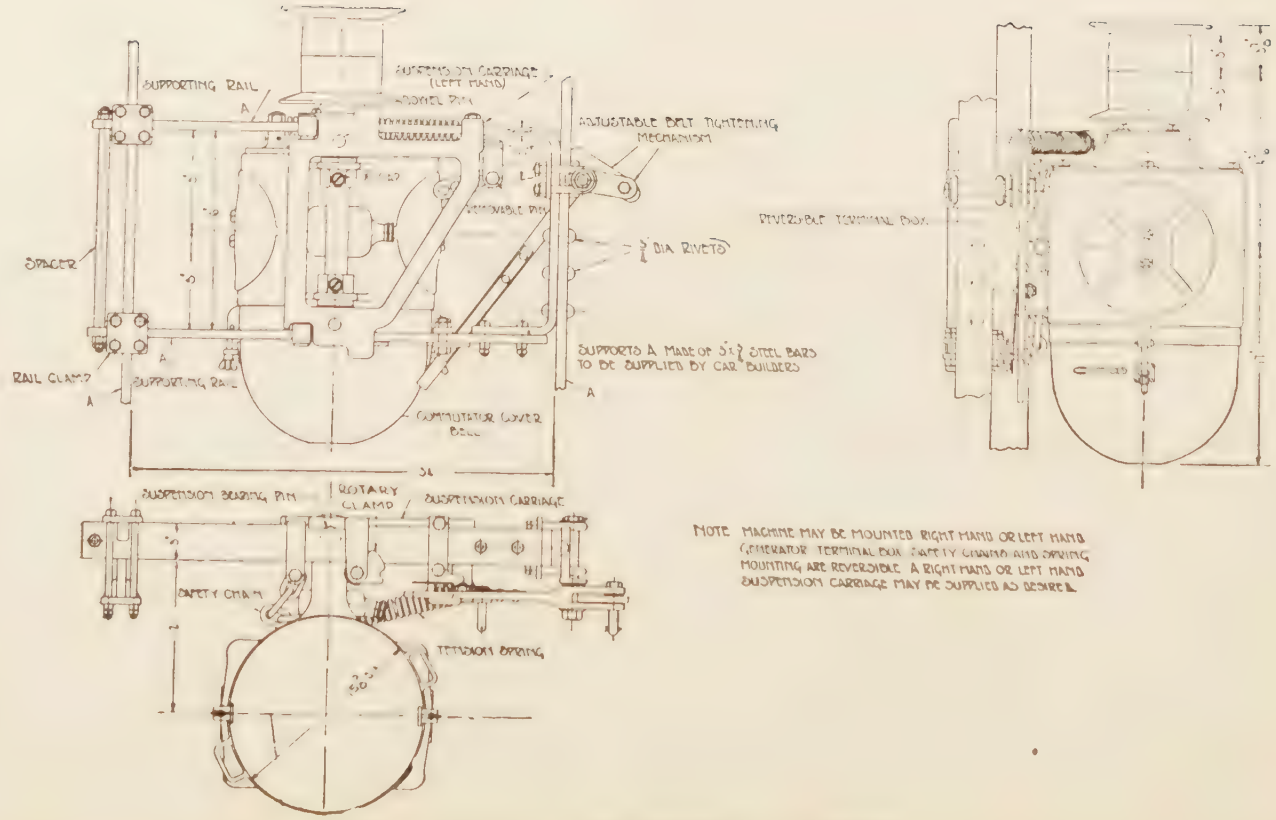

SUPPORTING RAIL
SUSPENSION CARRIAGE (LEFT HAND)
ADJUSTABLE BOLT TIGHTENING MECHANISM
REVERSIBLE TERMINAL BOX
SPACER
RAIL CLAMP
SUPPORTING RAIL
SUPPORTS A MADE OF STEEL BARS TO BE SUPPLIED BY CAR BUILDERS
COMMUTATOR COVER
SUSPENSION BEARING PIN
ROTARY CLAMP
SUSPENSION CARRIAGE
SAFETY CHAIN
TENSION SPRING
NOTE MACHINE MAY BE MOUNTED RIGHT HAND OR LEFT HAND GENERATOR TERMINAL BOX SAFETY CHAIN AND SPRING MOUNTING ARE REVERSIBLE A RIGHT HAND OR LEFT HAND SUSPENSION CARRIAGE MAY BE SUPPLIED AS DESIRED

FIG. 161—E. S. B. Body Suspension for Generator.

main switch shunt coil acts on a spring-supported armature to close the circuit of the pull-in coil.

This contactor is enclosed in a ring of high grade moulded insulation provided with suitable metallic inserts for terminal connections, with cover of same material.

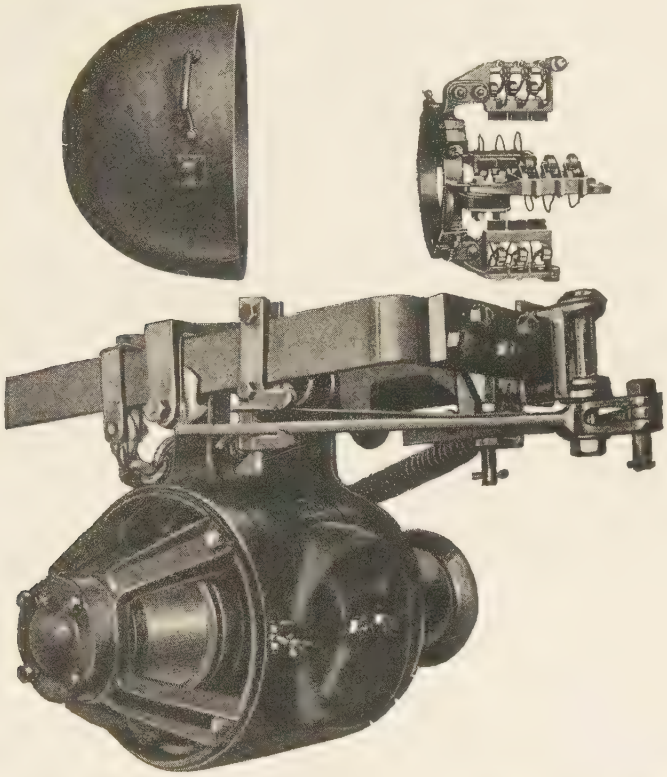


Fig. 162—Type D-3 Generator With Brush Rigging and Cover Bell Removed Showing Body Hung Suspension Arrangement.

Two of the terminal studs, one on either side of the main fuse, are made extra long to permit connecting an ammeter in the generator circuit, the fuse then being removed after the instrument is connected.

Each piece of apparatus on the regulator panel may be removed without disturbing the connections and without access to the back of the board. Every stud bolt passing through the board is

locked at the back so that it cannot turn when nuts are removed or replaced in front.

Body Suspension.—The E. S. B. Body-Hung Type Suspension is so constructed that belts can be easily applied. The belt tension is practically constant throughout the permitted swing of the generator on the suspension shaft. Ample provision is made for lining up the generator with the car axle. The generator is hung from a cast steel carriage which may be moved longitudinally on its supports by means of a hand lever. Suitable wedges or clamps are attached to the carriage for holding it securely in place on the supporting bars. The tension spring, when extended to its maximum normal position, produces a belt tension of only about

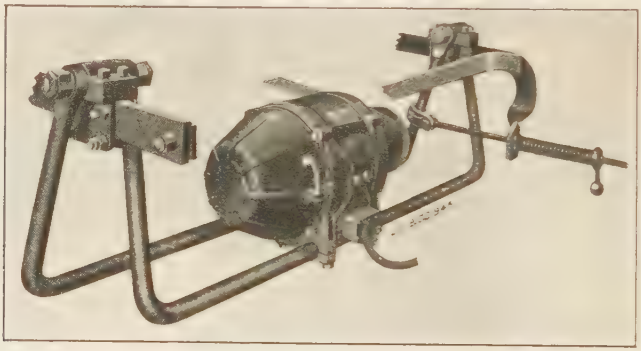


FIG. 163—Truck Type Suspension.

250 lb., which is a considerable factor in prolonging belt life. This suspension is shown in Figs. 161 and 162, and consists of a cast steel suspension carriage, supported on two horizontal bars, *A*, along which it may be moved by means of a hand lever toward or away from the truck. The belt tension spring is fastened at one end to the frame of the machine and at the other end to the suspension carriage. The belt tension is therefore applied or released by moving the suspension carriage away from or towards the truck by means of the hand lever. This lever is connected to the suspension carriage by a loosely pivoted link, whose effective length may be adjusted by reason of a series of holes at one end. In this way a quick adjustment may be made to provide for any stretch of the belt or for shortening when a

piece is cut out, and the proper belt tension may be maintained. In the running position the hand lever is held in position by a spring latch. Furthermore, the suspension carriage is firmly clamped to the horizontal bars by means of two rotary clamps whose clamping action may be applied or released by the tap of a hammer. The horizontal bars which support the suspension carriage are clamped at one end to a transverse supporting bar by means of vertical clamping bolts, permitting the dynamo to be properly aligned.

Truck Suspension.—The E. S. B. Truck Type Suspension—Fig. 163—is the original "two-point" suspension designed to

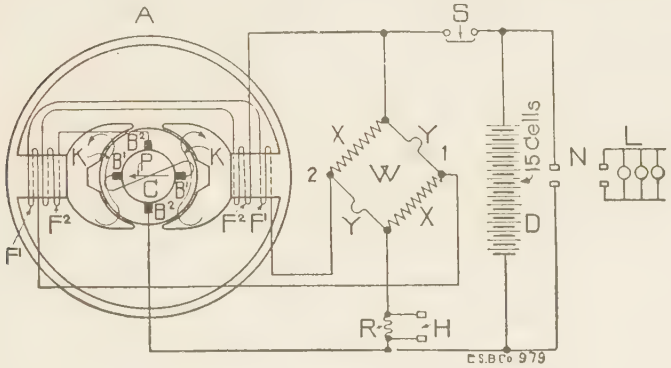


Fig. 164—Diagram of Circuits.

maintain permanent belt alignment and insure maximum belt life, and has successfully withstood the test of the severest service. The feet of the dynamo are rigidly clamped to the loop bars, there being no wear at these points. All wear is confined to the ample surface of two bearing pins free to rock in tubular steel bushings carried by the bearing saddles. In this type suspension the dynamo feet are clamped and locked solidly to the loop bars so that there is no wear in the feet of the machine. The loop bars at either end are clamped to the opposite ends of the large bearing pins, the pins being free to turn in tubular steel bushings clamped in the bearing saddle. Each pin provides a bearing surface 4½ in. long by 1¾ in. diameter. The bearing saddles are adjusted longitudinally on the side bars, which project from the truck frame. The bearing saddles are bolted and locked securely

on the side bars. It will be seen from the above that there are only two wearing parts to the suspension and these consist of tubular steel bushings having large bearing surfaces, which are easily and cheaply renewed. A grease cup is mounted on one end of each bearing pin by which suitable lubrication is secured.

Theory.—The E. S. B. generator is of the Rosenburg type whose main field is produced by a magneto-motive-force developed by the armature winding. It is illustrated diagrammatically in Fig. 164, and consists of a bipolar armature rotating between two heavy pole shoes, each shoe being connected securely to the frame of the machine by bolts passing through the pole cores. The pole cores are of small cross-section compared with the ordinary dynamo. Two pairs of brushes bear upon the commutator spaced 90 degrees apart, one pair being short-circuited, while the other pair is connected through the series winding to the external circuit. These brushes are designated respectively "short circuit brushes" and "load brushes."

On the pole necks are two field windings, F^1 and F^2. The series winding F^2 is connected between the top load brush and the generator terminal. The control field winding F^1 is connected across the Wheatstone bridge W and provides the primary field excitation controlling the voltage of the dynamo.

The magnetic field produced by this primary excitation passes across the armature in the direction of the arrow P and then through the pole shoes, pole necks and the frame of the machine. This magnetic field is, under normal conditions, of very small strength, producing a low voltage between the short circuit brushes B^1. This low voltage, however, produces a sufficient flow of current through the short circuit between these brushes and through the armature winding to develop a considerable magneto-motive-force. This latter magneto-motive-force produces a magnetic field at right angles to the primary field, which passes through the armature and pole shoes as shown by the arrows K, but which does not pass through the pole cores or frame of the machine. This secondary field flux produces the desired voltage across the load brushes B^2.

One of the principal results obtained with the Rosenburg type of machine is the development of the same polarity for either direction of rotation without employing any pole changer, or any alterations whatever in the circuit connections. This is due to

the fact that when the direction of rotation changes, the voltage generated across the short circuit brushes by the primary field is reversed and the current flowing between these brushes is, therefore, reversed in direction. This reverses the direction of the secondary field K, which produces the voltage across the load brushes B^2. It will be seen, therefore, that when the direction of armature rotation is reversed the direction of the main or secondary field excitation is also reversed, so that the polarity remains the same.

The E. S. B. Dynamo is controlled for constant voltage rather

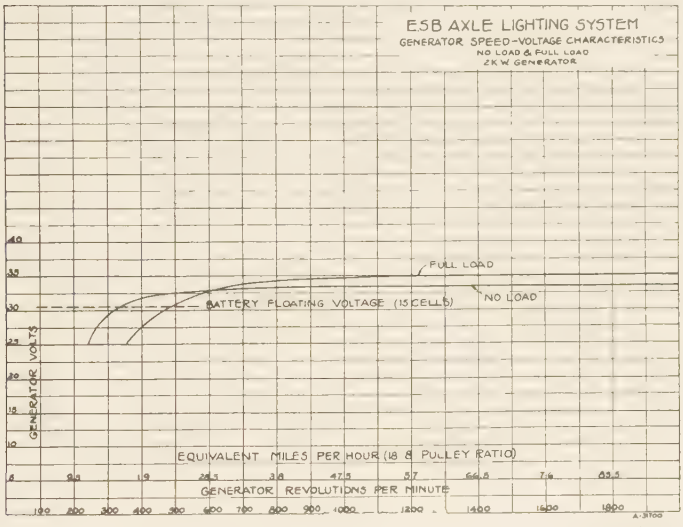


Fig. 165—Constant Voltage Characteristics.

than constant current, the voltage being held at approximately 33½ volts when used with 15-cell equipments. This control is effected by means of a Wheatstone bridge W, connected across the machine terminals at two opposite junction points of the bridge, while the other two opposite points are connected to the field terminals. The Wheatstone bridge consists of two fixed resistances, XX, and two wire "ballast" resistances, YY. The iron wire "ballast" resistances have the characteristic of increasing their resistance rapidly with very small increments of current when operating at a dull red heat. The design of this bridge (for 15-cell equipments) is such that when the machine voltage

is 33½ volts the resistances of X and Y are practically equal. Under these conditions no current will flow through the field winding, F^1. When the voltage is lower than 33½, the resistance of Y is less than the resistance of X, and Y will therefore carry more current than X, the excess current flowing through the field winding F^1. As the voltage of the machine increases, therefore, the field excitation becomes smaller and smaller, approaching zero as the voltage approaches 33½ volts. At high speed the current in the field is actually reversed in order to partly counteract the residual magnetism in the pole necks and the frame of the

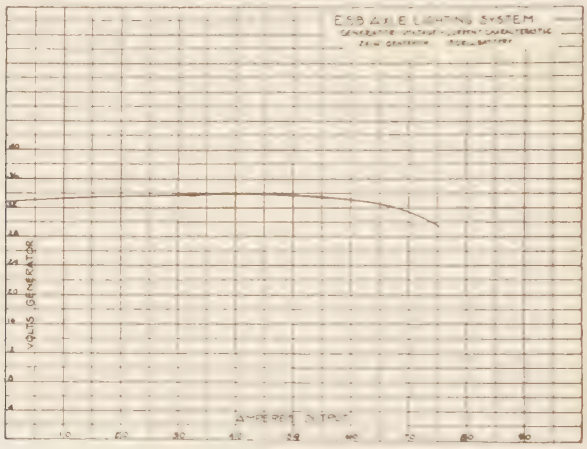


Fig. 166—Voltage at Various Loads.

machine. In series with the Wheatstone bridge is a fixed resistance R which is normally short-circuited by a copper rod H clamped between two binding posts. This is the normal position of the rod H. When this short circuit is opened by sliding the rod H out of contact with one of the binding posts, the drop in the resistance R lowers the voltage applied across the Wheatstone bridge, and in order to restore the latter to its normal balanced value, the voltage of the machine will be increased by an amount equal to the drop in the resistance R. The principal use of this device is to restore the voltage to normal in case of an open circuit in one of the bridge ballasts, if a renewal ballast is not immediately available.

Fig. 165 shows the constant voltage characteristics of the

dynamo when operating with the E. S. B. Wheatstone bridge control at various speeds. Two curves are given, one corresponding to no load, and the other corresponding to full load on the machine, the latter showing a higher voltage to compensate for line drop.

The E. S. B. dynamo is so designed as to protect itself automatically against excessive overloads. This result is accomplished by designing the machine to take advantage of saturation in the

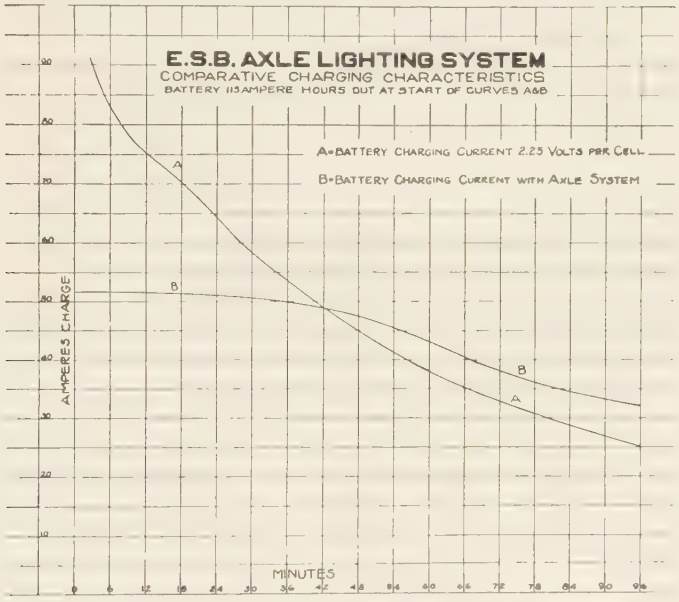


Fig. 167—Showing Output at Constant Potential and at Modified Constant Potential as Result of Compounding.

pole necks due to leakage flux, caused by the opposing effects of the series field and the armature reaction, and is inherent in the design of the machine and not dependent upon any automatic regulating devices. This characteristic is independent of speed and is shown on the characteristic curve, Fig. 166, which gives the voltage of the machine at various loads. It will be seen that the machine is slightly over-compounded to take care of drop in wiring up to approximately full load, at which point the voltage begins to drop with further increase of load. The result of this

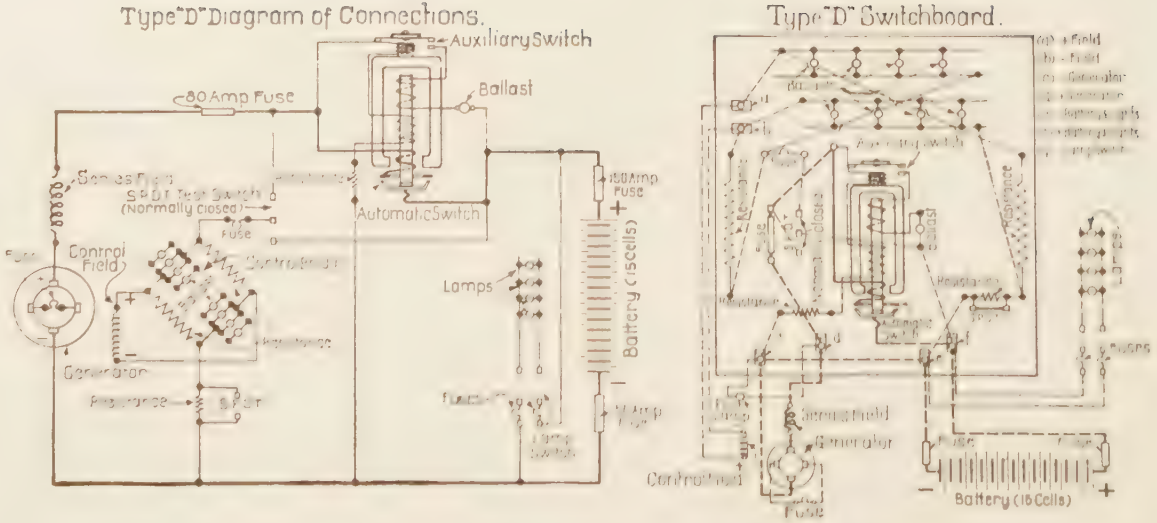


FIG. 168—Showing Type D Diagram of Connections and Type D Switchboard

dynamo characteristic in its effect on the charging current into the battery is shown in Fig. 167, in which two curves are given, curve *A* showing the charging current which would be put into a partly discharged battery if strictly constant voltage were maintained at its terminals, while curve *B* shows the input from E. S. B. dynamo designed to protect itself against excessive overload, as described above. It should be noted that this curve *B* applies to the 2 kw. machine, while the corresponding curve for the 3 kw. machine is proportionately higher.

Control Panel. The dynamo control panel is shown in Fig. 160, while in Fig. 168 will be found the diagram of connections at the left and the actual switchboard connections at the right. On the panel are mounted the resistances for the Wheatstone bridge control consisting of two fixed resistance units, one in each of two opposite branches of the bridge, and eight iron wire ballasts, four in each of the other two branches of the bridge; also a special spring retained double throw test switch which normally connects the positive generator terminal to the positive junction point of the bridge and is retained in this position by a small helical spring. By pushing the switch handle up against the force of the spring, the bridge positive is disconnected from the dynamo and connected to the battery positive, and since the negative bridge connects the common junction between the battery and the dynamo, this arrangement permits sending a current through the bridge from the battery when the car is standing. This current applied to the bridge for a few seconds will heat the ballasts and fixed resistances, enabling the inspector to determine that they are all in operative condition.

The automatic switch is provided with three coils wound about the plunger portion: the shunt coil, the "pull-in" coil and the series coil. The shunt coil is not of sufficient strength to close the automatic switch at normal voltage, but requires the assisting magneto-motive force furnished by the "pull-in" coil. The "pull-in" coil is connected between the dynamo positive terminal and the battery positive terminal whenever the dynamo voltage exceeds approximately 20 volts. The "pull-in" coil circuit is dependent upon the closing of a contactor which is located on the top of the automatic switch. The magnetizing coil for the contactor is connected in series with the automatic switch shunt coil and its

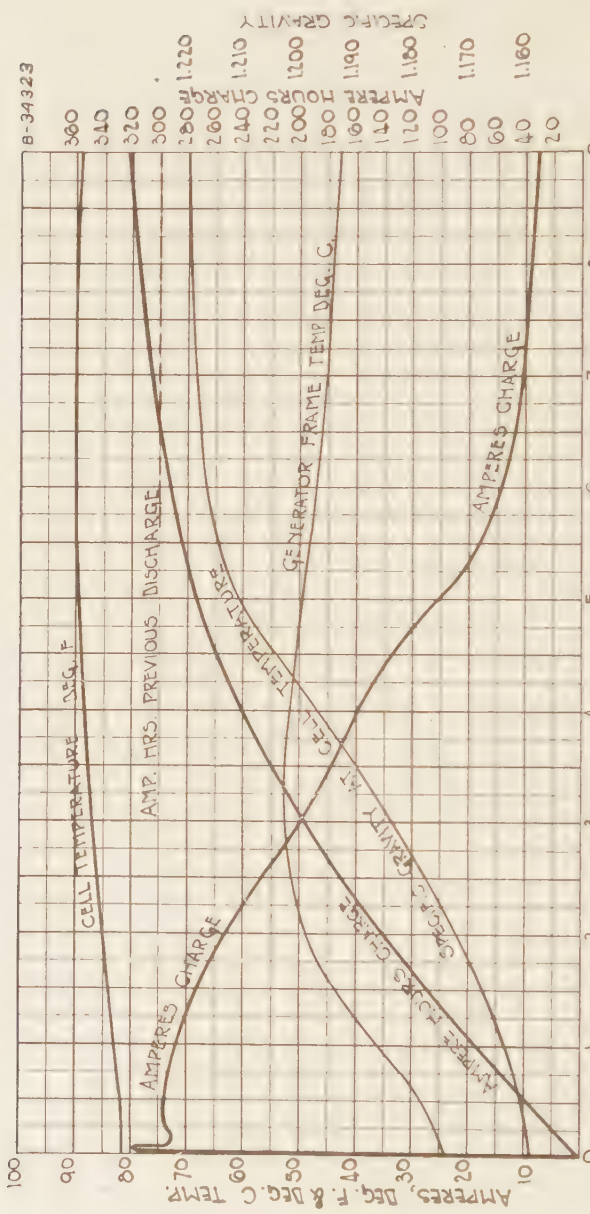


Fig. 169. Curve Showing How Charging Rate Tapers Off as the Battery Fills Up, in Such a Manner As to Keep Just Below the Gassing Point.

excitation therefore is proportional to the generator voltage. When the circuit of the "pull-in" coil is closed by this contractor, its excitation opposes the main shunt coil when the dynamo voltage is less than that of the battery. When, however, the voltage of the dynamo exceeds that of the battery by approximately one volt, the current in the "pull-in" coil is in the direction to co-operate with the main shunt coil to close the switch. The closing of the switch is therefore determined by the difference in voltage between the dynamo and the battery and when the battery voltage is low the switch will close sooner than when it is high.

When the dynamo voltage falls below approximately 20 volts, the contactor opens the "pull-in" coil circuit, thus preventing any flow of current from the battery back through this circuit via the dynamo armature when the car is standing. Thus, when standing there is absolutely no current taken from the battery other than that required for the lighting system.

The difference of voltage required to close the automatic switch is so small that not the slightest flicker can be observed in the lights when it closes; since the main coil acting alone is not sufficient to hold the switch closed, it will open with no appreciable reversal of current, and therefore without contact arcing and without flickering of the lights as the dynamo drops in speed.

On the lower part of the panel, at the left, is a fixed resistance in series with the shunt winding of the automatic switch. This resistance is unaffected by change of temperature and serves to limit the effect of temperature changes on the operation of the switch.

On the lower part of the panel, at the right, is the voltage-raising resistance unit and the rod for short-circuiting this is mounted directly beneath the unit.

The fuse to the left of the automatic switch is connected in the positive circuit of the generator. It is mounted on a removable insulating base provided with copper terminals for insertion in the fuse clips.

Characteristics of the E. S. B. Equipment.—The E. S. B. constant voltage system eliminates excessive overcharge and this in turn eliminates excessive gassing; this is illustrated in Fig. 169. When the battery is either partially or totally discharged, it is

recharged at a rapid rate. This rate, however, tapers off as the battery fills up, in such manner as to keep just below the gassing point; until, when the battery is full, the current input is reduced to a low trickling charge sufficient to keep the cells fully charged, but insufficient to injure the plates even if maintained indefinitely.

Referring to Fig. 169, note that it took but 6½ hours to restore the 300 ampere hours taken out of the battery before charging began. This was without gassing the battery and hence at a high rate of efficiency. At the same time it should be noted that

Steady Charging After Discharges of 50, 150 and 300 Ampere Hours. Sixteen Hours Idle Stand Between End of Discharge and Start of Charge. Cell Temp. 75° F. at Start of Charge.

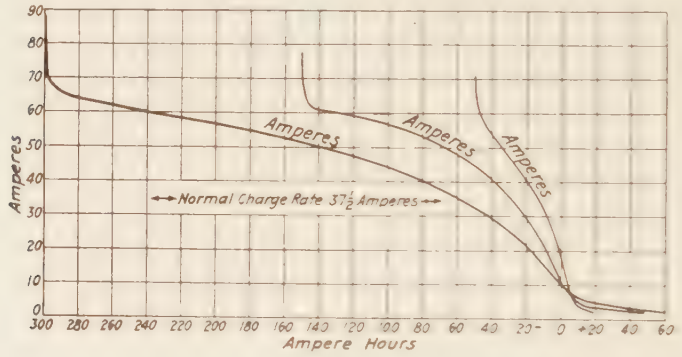


Fig. 170—Constant Voltage Charging—Performance Data.

during the first two hours the battery received 140 ampere hours charge at a time when it was most needed, in order to get the battery in operative condition as quickly as possible.

Note how, after the second hour, the specific gravity and ampere hour curve closely parallel each other and that the charging rate of the battery decreases as these curves rise.

The curves in Fig. 170 show why the constant voltage system is so effective in local suburban service with frequent stops. It will be seen that the charging rate immediate after a discharge is almost as great with a nearly full battery as with an empty battery.

The generator temperature curve reaches its maximum after three hours' continuous running. This maximum would, of

course, be considerably less under intermittent operation, such as is experienced on a train. It gives a good idea of the conservative rating of the generator and shows its ability to take care of any extra load, such as lamps, that might have been turned on at any period of the charging.

The graphic charts, Figs. 171a, b, c, d, show a characteristic of constant potential charging that is worthy of note. No doubt many storage battery operators now realize how rapidly and efficiently, and with what beneficial results storage batteries may be charged with constant voltage methods and are familiar with the general characteristics of such a charge starting with a fully discharged battery, but few men are informed regarding the results obtained with such charges considering batteries which have only been partially discharged. The graphic charts show the advantage of constant potential charging in car lighting service, especially in a service involving frequent stops.

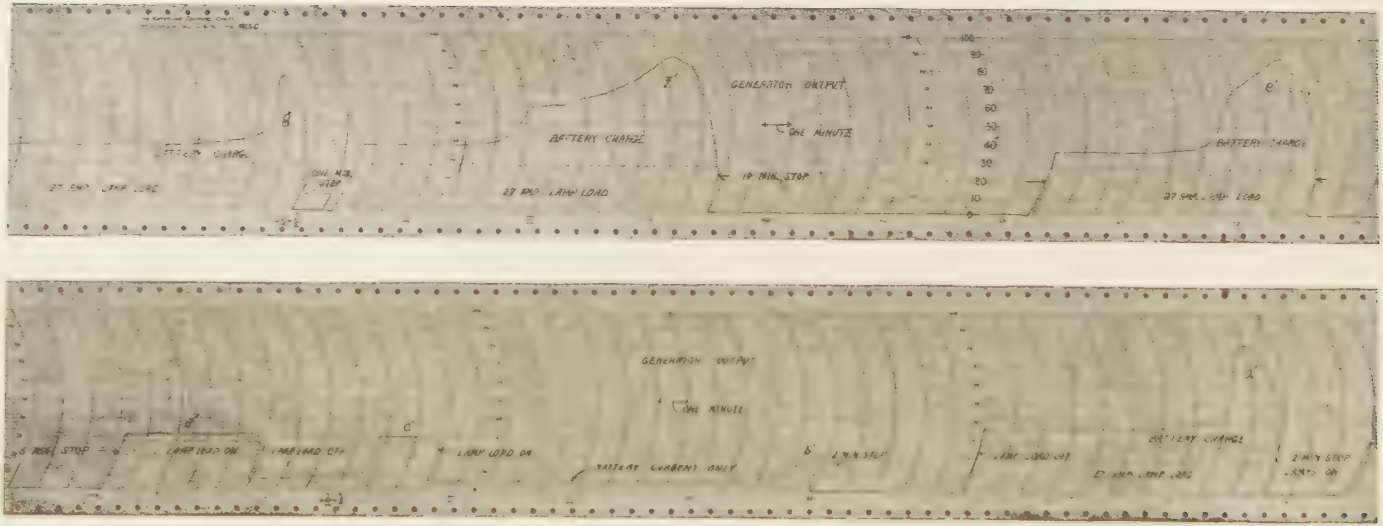
This equipment does not require a pole changer as the dynamo builds up with the same polarity for either direction of rotation, without any external change of connection.

Another characteristic is that no sneak current is taken from the battery when the equipment is standing with lights turned off, since every circuit on the control panel and dynamo is automatically disconnected from the battery when the car stops.

Another feature is that, should the polarity of the battery or dynamo be accidentally reversed, the equipment will automatically correct itself. For example, when the automatic switch closes, the polarity of the dynamo, if wrong, will be automatically reversed to correspond to that of the battery, without damage or blowing the fuses.

The overcharge capacity of the dynamo is available for at least two hours for rapidly charging an empty battery without danger of overheating the machine since the constant voltage control automatically reduces the charging current as the battery fills up.

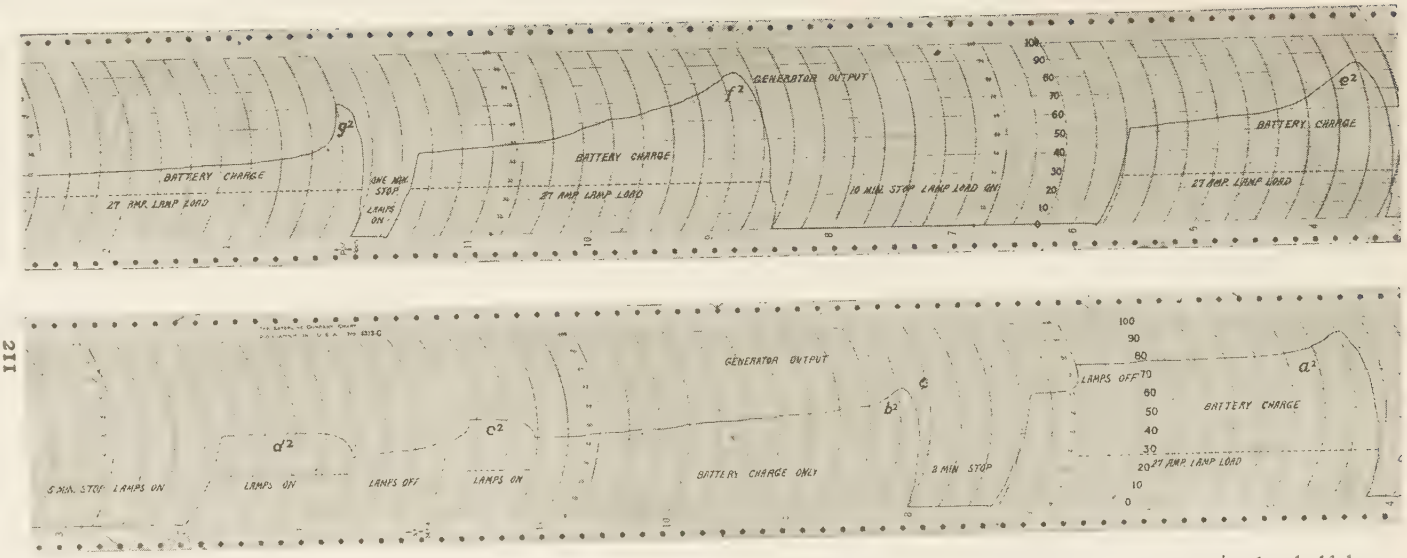
Excessive overload is prevented by the design of the pole cores which become saturated and reduce the voltage before a dangerous output is reached. This is true at all speeds. This last named characteristic is an important one since it will keep down the cost of armature repairs. The automatic switch closes when the volt



(A) At the beginning or right hand end of the curve the start is made with a full battery (lamp 27 amp. plus battery 3 amp.), total generator output 80 amp. Then after a two minutes' stop and discharge at 27 amps (54 amp. min.) the output rises to 82 amps. (lamps 27 plus battery 55 amps.) almost immediately tapering down. It will be observed that the current taken out of the battery at the two minute stop is quickly restored through the high output. The full battery condition then continues to the next five minute stop, after which it will be noted that the high output e' is retained for a longer period than at a' after the two minute stop. The same is noticeable after the ten-minute stop at f'. Note the difference between g' and a' one and two minute stops, respectively, where the former area is about half of the latter.

FIG. 171a—Graphic Chart Showing Characteristics of Constant Potential Charging in Car Lighting Service.

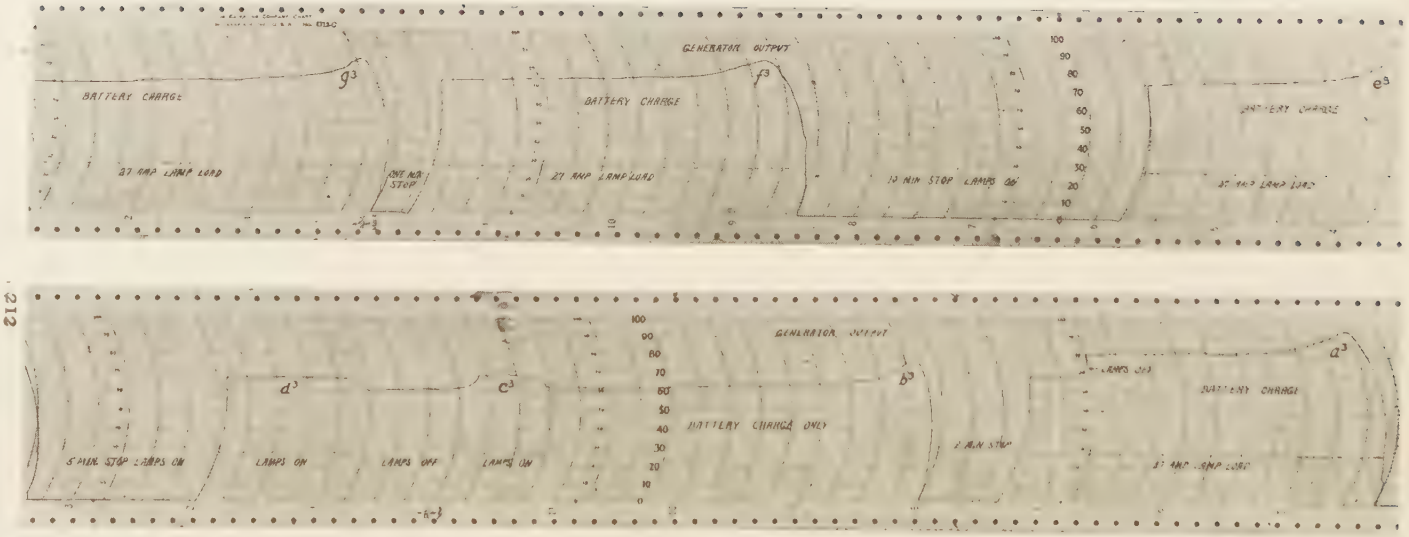
See also Figs. 171b, c, d, on pages 211 to 213.



(B) Is a duplicate of the run, shown on curve (A), except that the battery was discharged at 27 amps. for one and a half hours before starting up. Compare a^c with a^1, b^2 with b^1, and so on out to the last minute.

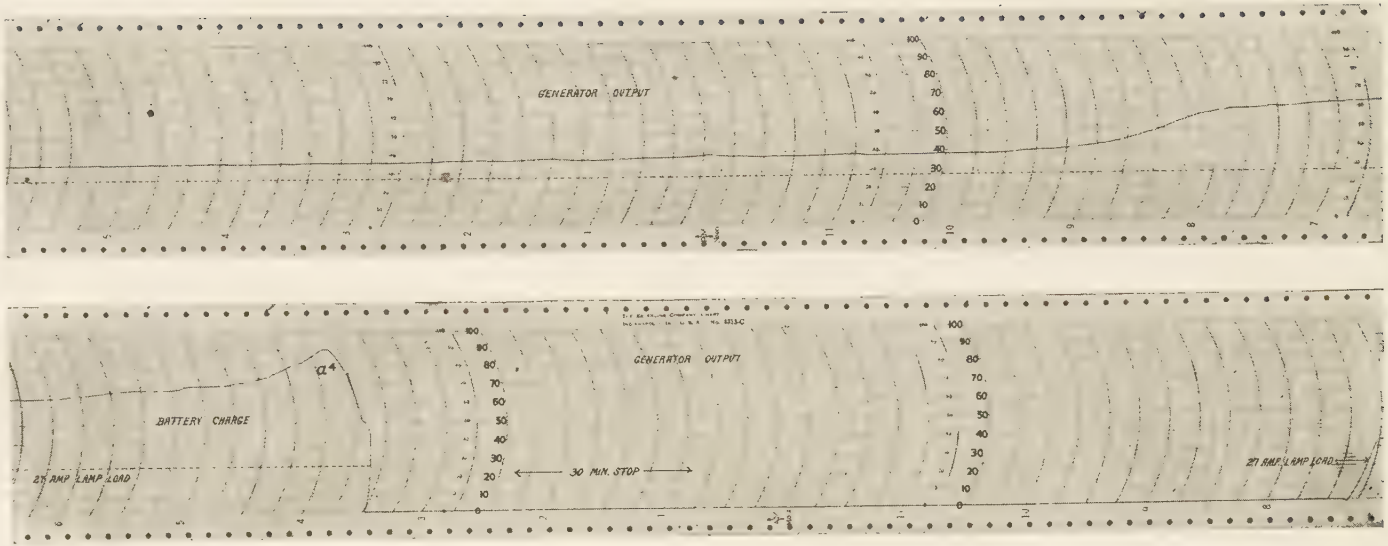
FIG. 171b—Graphic Chart Showing Characteristics of Constant Potential Charging in Car Lighting Service.

See also Figs. 171, a, c, d, on pages 210 to 213.



(C) Shows the same runs and stops except that the battery was discharged for three hours before the start at a^3.

FIG. 171c.—Graphic Chart Showing Characteristics of Constant Potential Charging in Car Lighting Service.
See also Figs. 171, a, b, d, on pages 210 to 213.



(D) Shows a continuous run with a 27 amp. lamp load, after a thirty-minute stop had discharged 13.5 amp. hours. Note that current taken out was put back in approximately two-thirds the time.

FIG. 171d—Graphic Chart Showing Characteristics of Constant Potential Charging in Car Lighting Service.
See also Figs. 171, a, b, c, on pages 210 to 212.

age of the dynamo is slightly above that of the battery and opens when the current from the dynamo drops to zero. Then there is absolutely no flickering of the lights, when the switch opens and closes, and no burning of switch contacts.

No adjustments of any kind are required with the E. S. B. system and no means of adjustment are provided. The equipment automatically adapts itself to all the varying conditions of service, such as changes of schedule, different hours of lighting in winter and summer, express train and local train service, branch line service, change of lamp load, etc.

Storage Battery.—The storage battery used with the E. S. B. lighting system is known as the "Exide" battery. It is of a special lead type; the "Manchester" positive plate and "box" negative plates are employed in its construction which is described in detail in Chapter VIII.

CHAPTER XVII

THE GOULD "SIMPLEX" SYSTEM

The Gould "Simplex" system of car lighting consists of a generator, driven by a belt from the car axle, a generator regulator panel, a lamp regulator panel mounted in a cabinet inside or under the car body, and a storage battery which is suspended in a box under the car body.

The fundamental principle of the Gould axle lighting system is the combination of a constant current and a constant voltage control, acting successively, which results in a straight line charge through the major part or the whole of the charging cycle followed by a period in which constant voltage is maintained while the charging current decreases to a low value. In the first "Simplex" regulators the voltage element was adjusted to maintain substantially the potential at which it first took over the control of the generator. The decrease of charging current then takes the form of a gradual taper to a low value, in the course of several hours. But, in the present standard regulators the voltage element is arranged to reduce the generator voltage quickly from the battery voltage at the end of charge—where the voltage element takes over the control of the generator—to substantially the floating voltage of the battery, which voltage is thereafter maintained. The charging current drops to a negligible value when voltage control begins.

For example, with a lead battery, and assuming that the current element is set for the desired charging rate of 45 amperes. If the equipment starts from a terminal with the battery discharged, a constant charging rate of 45 amperes is maintained until the battery is full. Meanwhile the battery voltage gradually rises, from about 36 volts to 39.5. At the latter point the potential element takes control and reduces the generator voltage to 36. Thereafter the battery floats across the line without receiving any

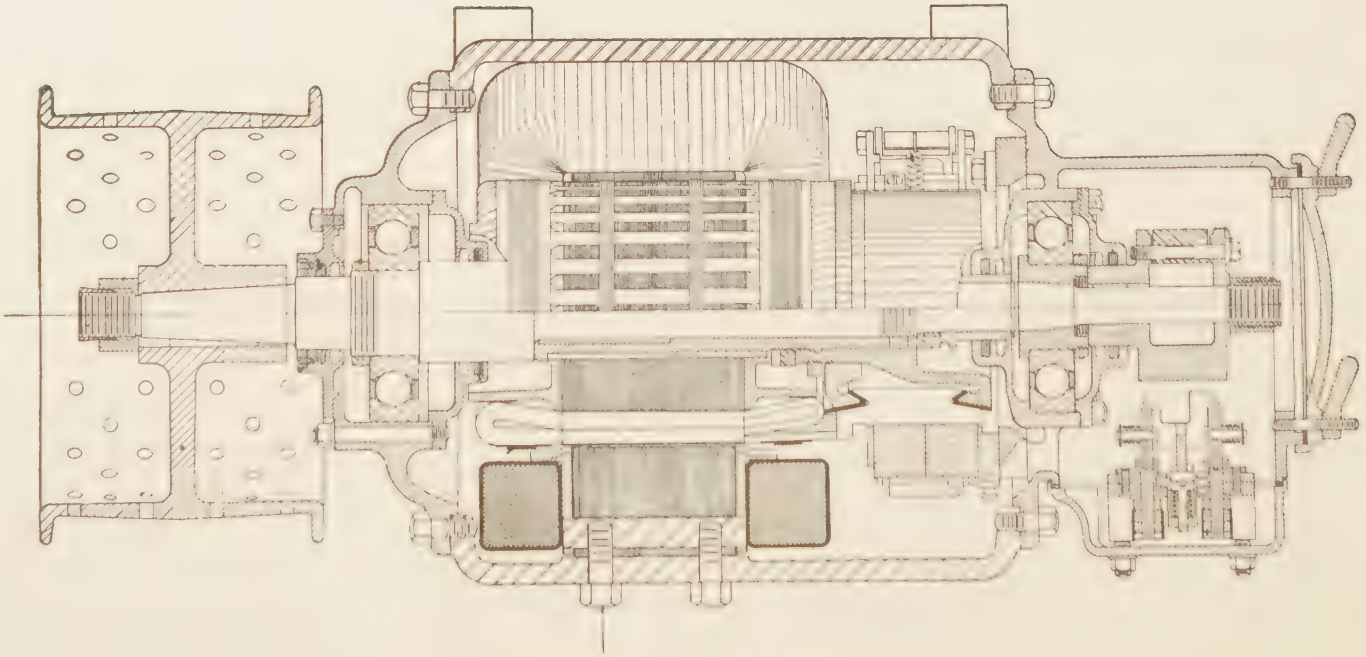


FIG. 172—Cross-Section of the Gould Axle Generator.

further substantial charge. Thus the start is with constant current regulation and changes to constant voltage regulation at the completion of the charge. With Edison batteries the regulator is generally set to take control at about 45 volts.

Generator.—The generator, a cross-section of which is shown in Fig. 172, is a four-pole, shunt-wound machine designed to give sparkless commutation throughout the range of loads and speeds met with in car lighting. The Gould generators are suitable for both body and truck suspensions. They are made in 1.4, 2, 3.4, and 4 kw. sizes, with speed ranges as shown in the table on page 219. As far as possible, similar parts are made to be interchangeable among the different sizes of machines; this flexibility is a decided advantage.

The generator consists of the following main parts: magnet frame, pole pieces, field coils, armature, bearings, pole changer, brush holders, and brushes.

The magnet frame is a one-piece steel casting; the supporting lugs being cast solid with the frame. The housing heads which carry the bearings are made of cast iron and bolted to the magnet frame at each end. Handholes, with water and dust-proof covers, are provided at the commutator end for inspection purposes. The pole pieces are of the laminated type, and bolted to the magnet frame. The armature is form wound with d. c. c. conductors. Each coil is thoroughly protected by tape, treated with insulating varnish and baked before placing in the slots, which are further insulated with heavy liners. The coils are held in the core slots by band wires.

The commutator bars are of hard drawn copper with liberal wearing depth and ample area to carry the maximum output of the generator.

The risers, to which the armature coils are connected, are integral with the bar. The mica insulation is of the best grade mica, having the same rate of wear as the commutator bars.

The armature shaft is made from high grade steel accurately ground to size. The pulley, in addition to having a tapered seat, is keyed to the shaft and locked with a Columbia lock nut. The bearings for the armature shaft are annular ball bearings, of a type especially developed for this service.

The pulley end bearing is pressed directly on the shaft and

held by a bearing nut. The commutator end bearing is similarly pressed and secured on a solid sleeve having a tapered bore to facilitate removal of the armature without disturbing the bearing. A space is provided around the bearings for grease for lubrication. Grease grooves and felt washers prevent the entrance of dirt into the bearings and the leakage of grease into portions of the dynamo where it should not go.

The brushes are made of carbon and provided with flexible copper pig tails to give positive contact with the brush box. The brushes are arranged in four metal holders, two positive and two negative, connected in parallel. The brush holders are permanently fixed in one position, being mounted on a Bakelite ring, which in turn is bolted to the commutator end housing.

The leads from the generator are brought to a terminal block at the top of an extension of the commutator end housing and the pole changer is mounted on the under side of this terminal block.

The function of the pole changer, which is of the mechanically operated switch type, is to maintain the proper polarity of the external circuit of the generator whether the car be running in a forward or backward direction.

When the direction of generator rotation is reversed, it develops reverse polarity; that is, the positive generator brush becomes negative and the negative becomes positive. The pole changer, however, is automatically thrown to the opposite side, reversing the main armature leads to the brush holders, so that correct polarity of the external circuit of the generator is maintained.

The operation of this type of pole changer is illustrated in Fig. 30 on page 31 and Fig. 30a on page 32. It consists of a double-pole double-throw knife switch connected between the brush leads and the external leads of the generator, and a trip which is arranged in a carrier and mounted on the armature shaft. The trip has two horns which register, respectively, with a front and a rear projection on the switch bridge. During the first revolution of the generator in either direction, one horn or the other engages the corresponding projection on the switch bridge and throws the switch to the position corresponding to the direction of rotation. A spring toggle carries the bridge beyond the

reach of the tripping horn and retains it in the new position. Thereafter the trip revolves without touching the bridge, until the direction of rotation is reversed.

The following table gives the characteristics, weight, etc., of the various sizes of Gould axle generators.

Type	"AB"	"GB"	"BB"	"CB"	"R"	"R"	"BBX"
Rating	1.4 kw.	2 kw.	3.4 kw.	4 kw.	2 kw.	3 kw.	2 kw.
Amperes	35	50	85	100	50	75	50
Volts	40	40	40	40	40	40	40
Cutting in Speed R. P. M	350	385	390	385	465	720	265
¾ Load Speed R. P. M.	430	480	490	480	585	900	335
Full Load Speed R. P. M.	460	510	520	510	620	950	350
Weight of Generator without Pulley	485	550	655	840	540	540	655
Weight of Armature	75	95	155	180	90	90	155

Generator Regulator.—The Gould Type BB-9-B generator regulator panel is shown in Fig. 173. It consists of a slate panel on which are mounted the automatic switch, field rheostat or carbon pile, two solenoid coils with their respective plungers and connecting lever arms, main fuse and various resistance units.

The automatic switch is of the double break, laminated copper contact type with auxiliary carbon break and is closed against the action of gravity by the lifting of its solenoid core. There are two windings on the solenoid, one a shunt coil across the generator mains, the other a heavy series coil connected in series with the generator mains. In series with the shunt or lifting coil is a heat compensating resistance unit mounted on the automatic switch frame. When the generator voltage reaches 33 volts the shunt coil becomes sufficiently energized to raise the plunger and close the switch. The series coil is then energized and assists in holding the contacts of switch, closed. Should the generator speed be decreased and its voltage dropped below that of the battery, the latter tends to discharge through the series coil in an opposite direction, thereby neutralizing the pull of the lifting or shunt coil. Gravity, reinforced by the switch springs, then causes the switch contacts to open. On some of the older types a metal disc mounted on top of the solenoid plunger makes contact with laminated copper brushes and serves to short-circuit the series coil of the regulator when the automatic switch is open.

Current passing from the battery to the lamps which would tend to raise the plunger, increase the carbon pile resistance and retard the picking up of the generator is thus shunted around

the regulator coil. But the short-circuiting contact is now omitted because experience shows it to be unnecessary at the present customary lamp loads.

The field rheostat or carbon pile shown at the top of the regulator panel is connected in series with the field circuit. The resistance of this carbon pile is automatically adjusted by the

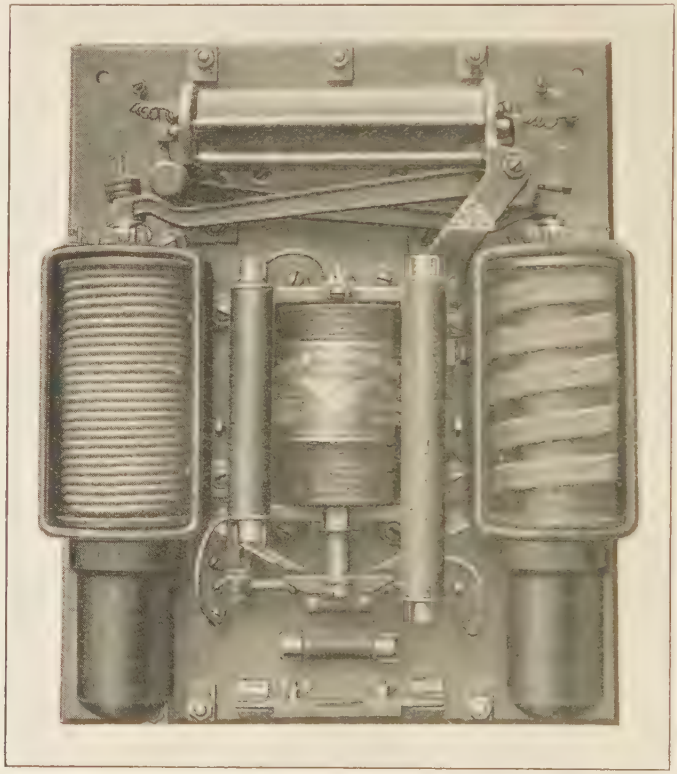


Fig. 173—Generator Regulator Panel Type BB-9-B.

movement of the plungers of the regulating solenoids. The shunt or potential regulating coil, located at the right of the regulator panel, controls a plunger whose lever arm acts directly on the pressure plate at the left end of the field carbon pile. This coil is connected in series with the heat compensating resistance unit located on the right-hand side of the frame of the automatic switch—see Fig. 173—the circuit then being connected across the

generator leads. On the surface of this coil is a differential winding, consisting of a few turns of strap copper, connected in series with the battery branch. The potential coil alone is adjusted to maintain the generator at the floating voltage of the battery. But during the charging period it is opposed by the charging current in the differential winding, so that the plunger does not rise until the battery attains the maximum charging voltage. It then assumes control, and as the charging current diminishes it regulates for progressively lower voltage until the charging rate has dropped substantially to zero and the voltage setting to the floating voltage of the battery. The result is a rapid transition from the full charging rate to a negligible charge.

The series regulating coil located at the left of the regulator panel is made of heavy copper wire through which flows either the battery current, or the total generator current, as desired. The series regulating coil controls a plunger whose lever arm acts directly on the pressure plate at the right end of the field carbon pile.

The resistance unit located on the regulator panel below the automatic switch is known as the exciter unit and is connected so as to allow a current of low amperage to flow through the armature and field circuits when the generator is inoperative.

The main fuse is located on the regulator panel below the exciter unit.

Fig. 174 shows the AB-9-B Generator Regulator which is sometimes used in place of the BB-9-B when the lamp load is moderate and close maintenance of lamp voltage is not required. The generator regulating elements are identical in principle with the BB-9-B regulator. The heat compensating resistance units for the potential solenoid and automatic switch are mounted on the panel below the automatic switch. The coil of a magnet switch at the upper left hand corner of the panel takes the place of the exciter resistance unit in the generator control circuits. When the automatic switch is open the current in the exciter circuit closes the magnet switch and short circuits fixed resistance units, one of which is provided for each of four lamp circuits. Thus when the automatic switch is open the lamps receive current from the battery without any intervening resistance. But, when the generator is operating and the automatic switch closed, a resistance

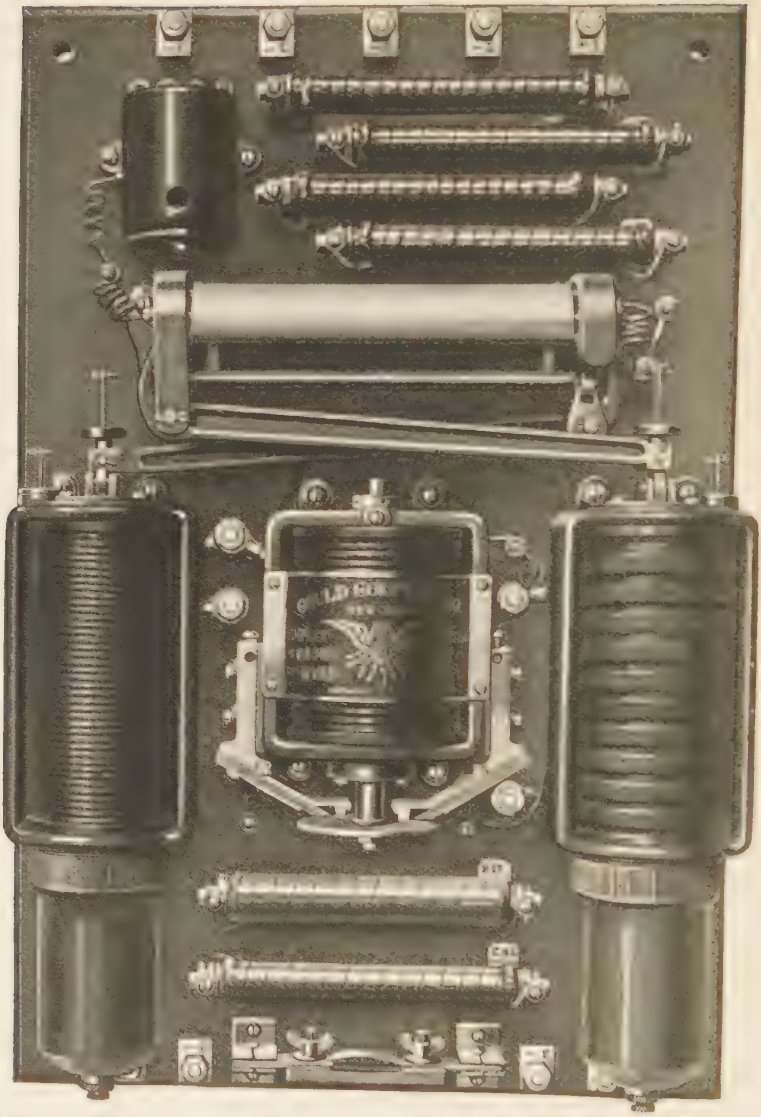


Fig. 174. Gould Generator Regulator and Lamp Controller—Type AB-9-B.

is inserted in each lamp circuit to absorb the average excess of battery voltage during charge over normal lamp voltage.

Lamp Regulator.—The function of the Gould Simplex lamp regulator, Type M-2—Figs. 175 and 176—is to maintain constant

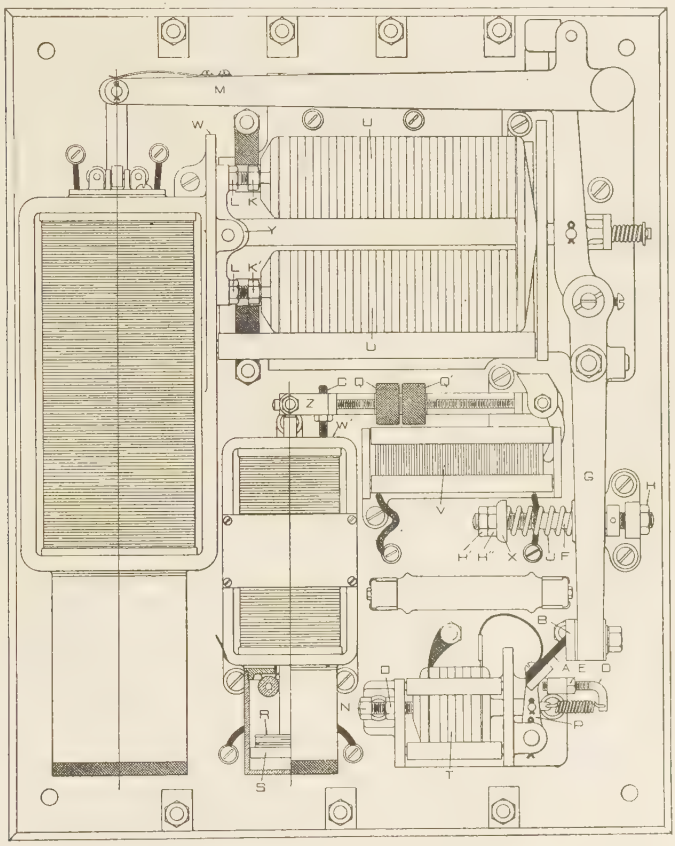


Fig. 175—Outline Drawing Showing Arrangement of Apparatus on the Types "M" and "M2" Lamp Regulators.

lamp voltage when the battery or generator voltage rises above the normal lamp voltage. It consists of a slate panel upon which are mounted the main solenoid coil, with its plunger and connecting lever arms *M* and dash pot; main carbon piles *U* connected in series or multiple, according to the load; short circuiting carbon pile *T* with contacts *A* and *B;* multiplier solenoid coil

with its plunger, lever arm, and dash pot; multiplier carbon pile V; and a multiplier heat compensating resistance unit.

The main solenoid coil is connected in series with the multiplier carbon pile V and the circuit is connected across the lamp mains.

The main carbon pile is connected in multiple with the short

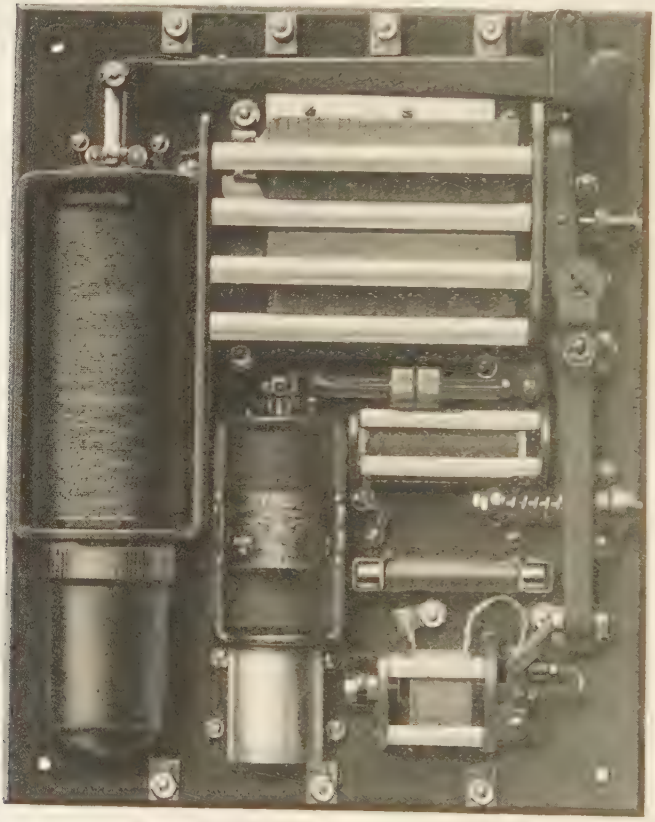


FIG. 176—Gould Lamp Regulator—Type M-2

circuiting carbon pile T and the circuit is connected in series with the lamps.

The short circuiting carbon pile is controlled by the short circuiting make and break A and B to the right of the pile T.

Since the circuit of the main solenoid is connected across the lamp mains, any increase of lamp voltage above normal will

directly increase the pull of the solenoid. At the same time it will increase the pull on the multiplier solenoid and the pressure on the multiplier carbon pile, which is in series with the main solenoid, diminishing its resistance and still further increasing the current through the main solenoid. Consequently a very small variation of lamp voltage above or below normal suffices to operate the main solenoid through its whole range of motion. In other words, the regulator is extremely sensitive to small variations of lamp voltage.

When the voltage supplied to the lamp regulator is above the normal lamp voltage, the lever *M* rises. The floating lever shown in contact with *M* follows it and allows the spring *U* to force the lever *G* back against its stop, opening the contacts *AB* in series with the short carbon pile *T*. The total lamp current now passes through the main piles *U*. Further movement of the main solenoid plunger and the lever *M* reduces the pressure and increases the voltage drop in the carbon pile *U* until the lamp voltage is restored to normal. Equal division of pressure and resistance in the two main carbon piles is assured by an equalizing lever *Y* at the left end of the piles.

If the supply voltage is reduced, the main plunger and the lever *M* move downward, increasing the pressure on the main carbon piles as required to maintain normal voltage at the lamps. If the drop in the main piles when fully compressed still exceeds the required drop, further movement of the lever *M* acts through the floating lever to force the lever *G* over against its spring, closing the contacts *AB*, which connect the short pile *T* in multiple with the main piles, and finally compressing the pile until the lamp voltage is restored to normal, or until the drop in the regulator has been practically eliminated; for the pile *T* has only a few contacts in series and its resistance when compressed is extremely small. When the battery is supplying current for the lamps at or slightly below the normal lamp voltage, this feature makes it possible to maintain substantially full battery voltage at the lamps instead of two or three volts less the battery voltage as in regulators without the short circuiting pile.

In some cases where refinement of regulator can be sacrificed for the sake of simplification, the M-3 type of regulator is substituted for the M-2. This type, which is shown in Fig. 177, is identical with the M-2, except that the multiplier and the short

circuiting carbon pile are omitted, and heat compensating resistance units are used in series with the main solenoid.

Generator Suspension. Gould axle generators are suspended either from the truck or the body.

The truck suspensions are of the two-point link type, as shown

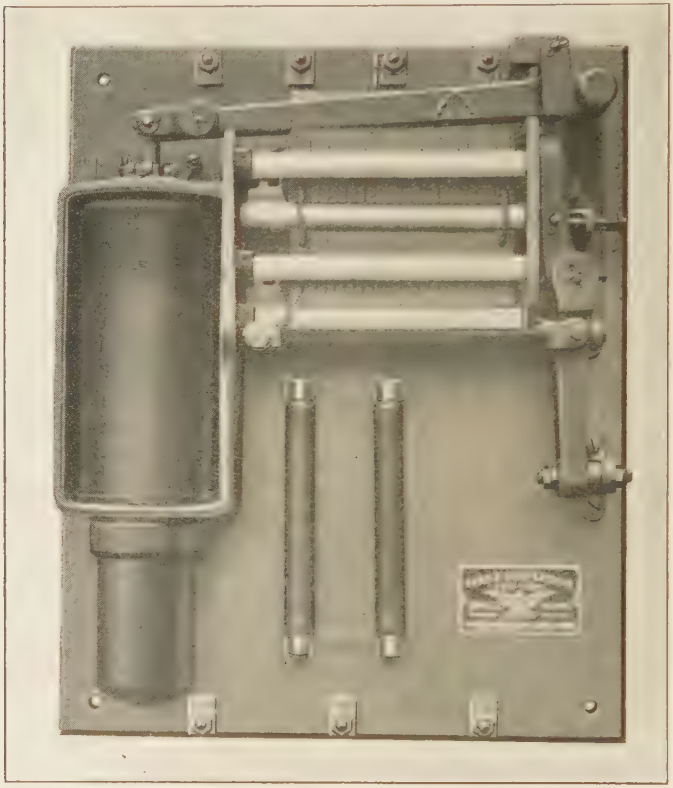


Fig. 177—Lamp Regulator Panel—Type M-3.

in Fig. 178, or four-point link type, as shown in Fig. 179. The same generators may also be suspended from the car body by using the adapter type body suspension as shown in Fig. 180. The Type R generators are provided with integral suspension arms for body mounting only.

Operation.—Fig. 181 is a wiring diagram of the Simplex axle lighting system, using BB-9-B and M 2 regulators. Its operation is as follows: When the car is standing still and the generator

inoperative the current to the lamps is furnished by the storage battery. When the car is in motion the generator voltage will build up, due to the residual magnetism of the field pole pieces and the magnetism produced by the flow of the exciter current through the field coils. At slow speeds there is generated in the armature a low voltage which forces a small amount of current through three parallel circuits, comprising the automatic switch lifting coil circuit, the field circuit and the voltage regulating coil circuit.

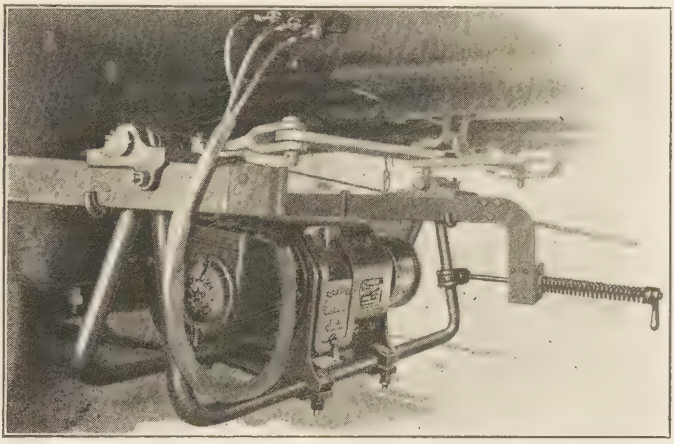


FIG. 178—Two Point Bearing Truck Type Suspension.

As the speed of the armature increases the generator voltage increases until it reaches 33 volts, at which time the automatic switch closes and connects the generator to the car wiring.

The instant the automatic switch closes, all circuits become energized, the machine then furnishing current for any lamps that may be turned on, but delivering only a small amount of current to the battery. As the speed increases the generator voltage rises and increases the battery charging current until it reaches the value for which the series regulating solenoid is set. Any increase in current above this amount produces a magnetism of sufficient strength to lift the plunger and its lever arm, which movement is transmitted to the field carbon pile, increasing the resistance of this carbon pile and reducing the field magnetism until the current falls to its normal value. In this way the battery

charge is held practically constant at all speeds when the battery is in need of charge.

From the instant that the generator starts to build up, the voltage regulating coil is alive, but, up to the time when the automatic switch closes, the generator voltage is insufficient to lift the plunger, and thereafter the voltage coil is opposed by the battery current winding which surrounds it. Consequently, the plunger does not lift until the battery voltage—which increases gradually during the charging period—has reached substantially its final value—generally 40 volts for lead battery or 45 for

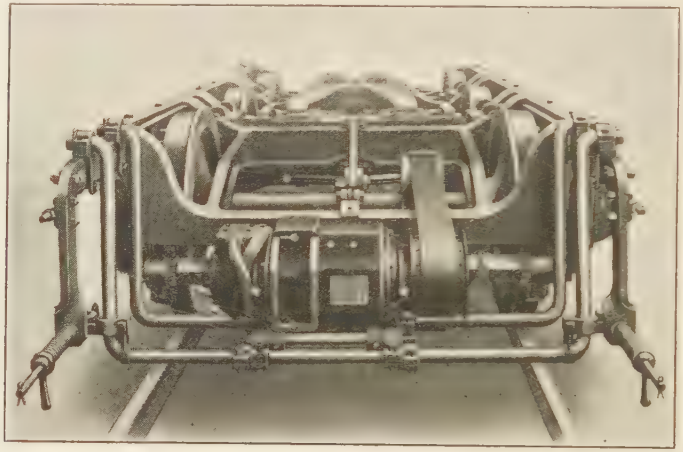


Fig. 179—Link Type Four Point Bearing Truck Suspension.

Edison battery. At this point the potential plunger rises and relieves the pressure on the carbon pile; the generator voltage is slightly reduced and the charging current begins to fall off. The opposition of the differential battery current winding is consequently reduced, allowing the plunger to rise still further, and further reduce the generator voltage. This cycle of events repeats itself until, in a short time, the charging current has practically ceased to flow. Thereafter the regulator maintains constant generator voltage while the battery floats on the line. Even if the battery circuit becomes open circuited the same generator voltage is maintained.

The voltage setting for Edison batteries is considerably higher than for lead batteries, but the same regulator can be used for

either type of battery by changing the heat compensating resistance unit in the potential regulating circuit. A certain current in this circuit is required to lift the solenoid plunger, and evidently the higher the resistance of the compensating unit the higher will be the voltage at which the required current will flow in the circuit.

In Fig. 181 it will be noted that the current regulating coil is in the battery branch circuit, beyond the point where current for the lamps branches off. During the current control period

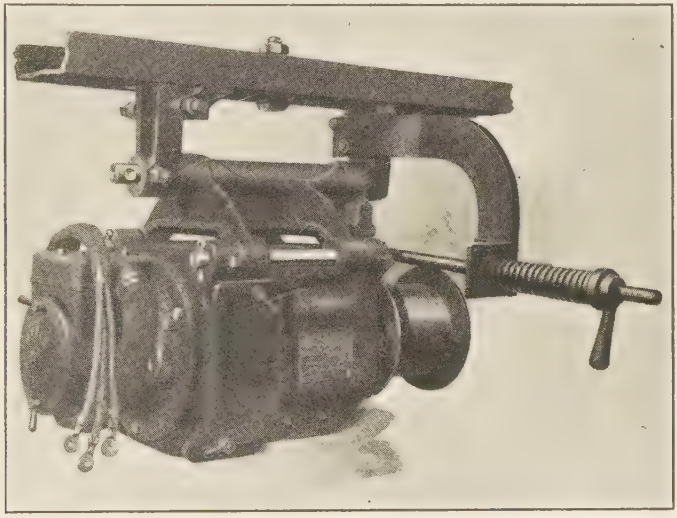


Fig. 180—Adapter Type Body Suspension.

the regulator acts to maintain constant current *in the regulating coil,* and hence, in this case, in the battery circuit. The charging rate is held constant irrespective of the lamp load, and in addition the generator supplies whatever current the lamps require. When constant generator output is desired the current regulating coil is connected in the generator circuit ahead of the branch leading to the lamps. The total output of the generator is then held constant and the battery charging rate varies with the number of lamps turned on.

Operation of the Lamp Regulator.—Referring to the wiring diagram, Fig. 181, it may be noted that the current to the lamps

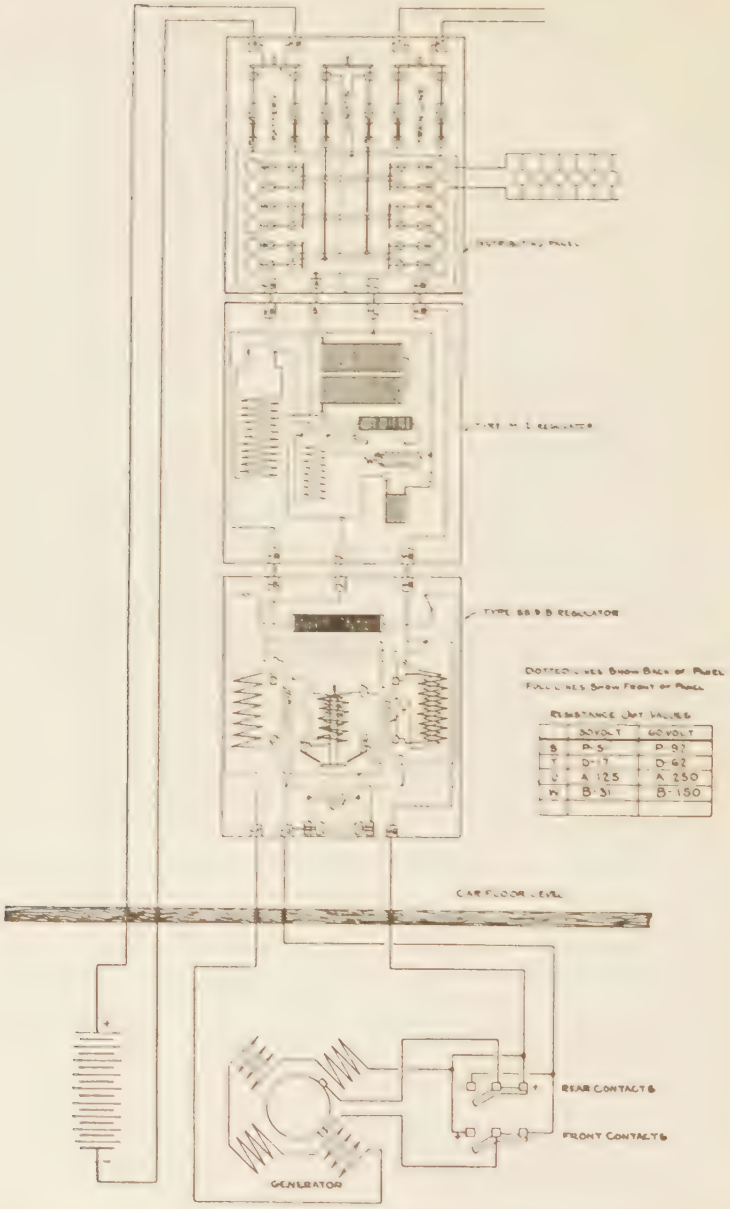


FIG. 181—Wiring Diagram of Type BB-9-B Generator Regulator Connected for Constant Battery Charge + Lamp Load; Type M-2 Lamp Regulator and 6-Circuit Distributing Panel.

from the battery or generator passes through the two main carbon piles. It may also be noted that the multiplier solenoid coil circuit and the main solenoid coil circuit are connected across the lamp circuit on the load side of the main carbon piles. Therefore the rheostatic effect of the carbon piles governs both the lamps and the operating circuits of the regulator. The lamp regulator is adjusted to maintain the lamp voltage at the standard adopted by the railroad, ranging from 30 to 32 volts on different roads.

A sudden decrease in lamp load will momentarily subject the lamp circuit to a higher voltage, but the same high voltage is impressed upon the multiplier solenoid coil forcing increased current through this circuit, which action results in sufficient increase in magnetism to lift the plunger of the multiplier solenoid coil and increase the pressure on the multiplier carbon pile. As this pressure is increased the current is increased in the main solenoid coil circuit, which action results in sufficient increase in magnetism to lift the plunger of the main solenoid. This decreases the pressure on the main carbon piles and increases the drop in the piles till normal voltage is reëstablished on the lamps and on the main and multiplier solenoids. The mechanical and electrical forces will then balance and no further movement will occur until there is a further change in voltage.

If the lamp voltage drops below normal, the reverse action takes place: The magnetic effect of the main and multiplier coils is reduced and this in turn reduces the voltage drop of the main carbon piles, increasing the lamp voltage. This increase continues until the regulator reaches its balanced condition and the lamp voltage becomes normal.

Fig. 182 shows connections with the M-3 lamp regulator in which the multiplier is omitted, and Fig. 183 shows the connection of the AB-9-B regulator in which a magnet switch and fixed resistance units are substituted for the lamp regulator.

Adjustment of Generator Regulator.—The guide rollers on top of the solenoid frame, Fig. 173, constitute the stops for the extreme downward travel of the actuating levers. In placing the carbon discs in the support rack, just enough discs should be placed therein so that when both levers are down—the regulator at the time being inoperative and the discs cool—one lever should be from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. off its stop with the other resting on its stop. Under these conditions the carbon pile is under its greatest

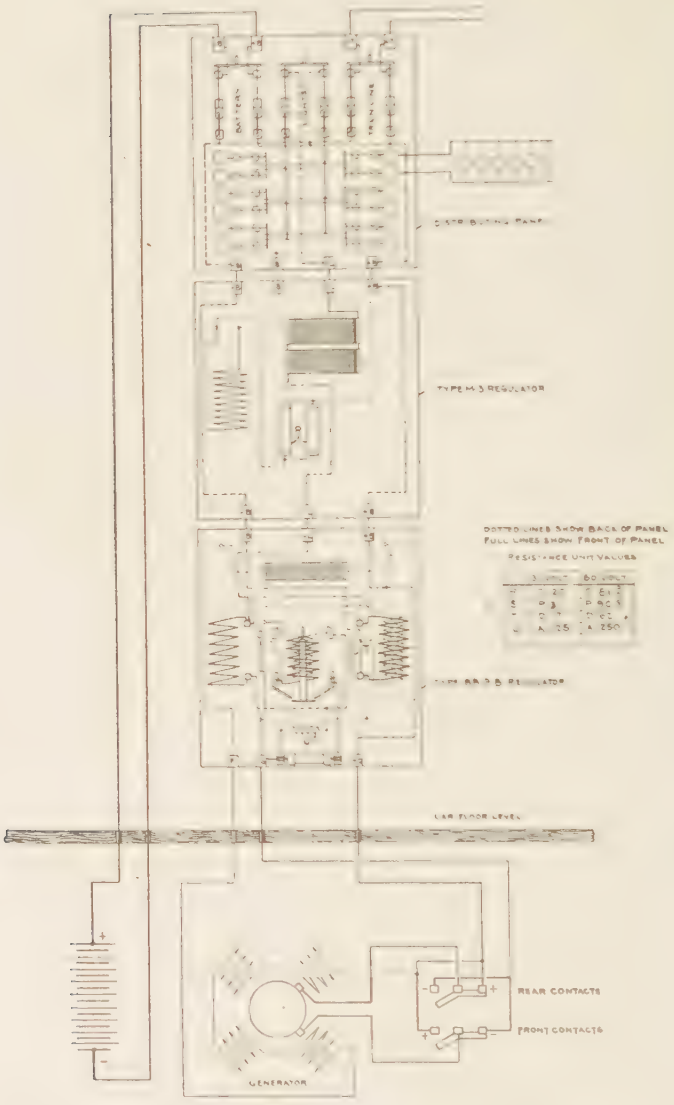


FIG. 182—Wiring Diagram of Type BB-9-B Generator Regulator Panel, and Type M-3 Lamp Regulator Panel.

compression and the generator can then get its maximum excitation. The current and potential control solenoids are adjusted and balanced against their respective magnetic pulls by weights riveted to the dash pot pistons or applied to pins on the ends of the levers. These adjustments are made at the factory at their proper values corresponding with the rating of the generator and must not be changed, unless a change in controlling value is desired.

Adjusting the Automatic Switch.—The automatic switch is set and adjusted at the factory to cut in and out at 33 volts. Should it be desired to change this adjustment proceed as follows:

Loosen the set screw at the top, which locks the upper core; then screw the core in to make the switch cut in at lower voltage, or screw the core out to raise the cutting-in point. The carbon contacts should engage $\frac{1}{16}$ in. ahead of copper contacts, and the carbons should be kept adjusted to this distance at all times. On the older types of regulators where auxiliary contacts are provided on top of the automatic switch, the upper and lower metallic contacts should be so adjusted that the upper contact opens when the lower metallic contact has been compressed approximately $\frac{1}{64}$ in. This is to insure a firm connection on the lower contacts before opening the upper contacts and in the opening of the switch to insure the closing of the upper contact before breaking the lower metallic contact.

Adjusting Type M-2 Lamp Regulator.—In adjusting the Type M-2 lamp regulator, Fig. 175, block the main lever *M* in a position at least 1 in. above the stop *W*, and adjust stud *F* so that the lever *G* is in a vertical position, then adjust *D* stud so that the tip of brush *A* will be separated by about $\frac{1}{32}$ in. from contact button *B*. Then readjust the stud *F* so that the tip of brush *A* is exactly $\frac{1}{32}$ in. from contact button *B*. Lock the studs *D* and *F* in these positions by nuts *E* and *H*, respectively. Next, by means of the cap screw *N*, adjust the short-circuiting carbon pile *T* so that, with the carbon plates normally in very loose contact, the movement of the lever *P* necessary to cause an increase of $\frac{1}{32}$ in. in the gap between brush *A* and button *B* will bring the carbon plates in pile *T* under full compression. Lock the cap screw *N* in this position by tightening the nut *O*. The spring *J*, which controls the degree of compression reached in the main carbon piles *U* and *U'*, should be compressed until the distance between

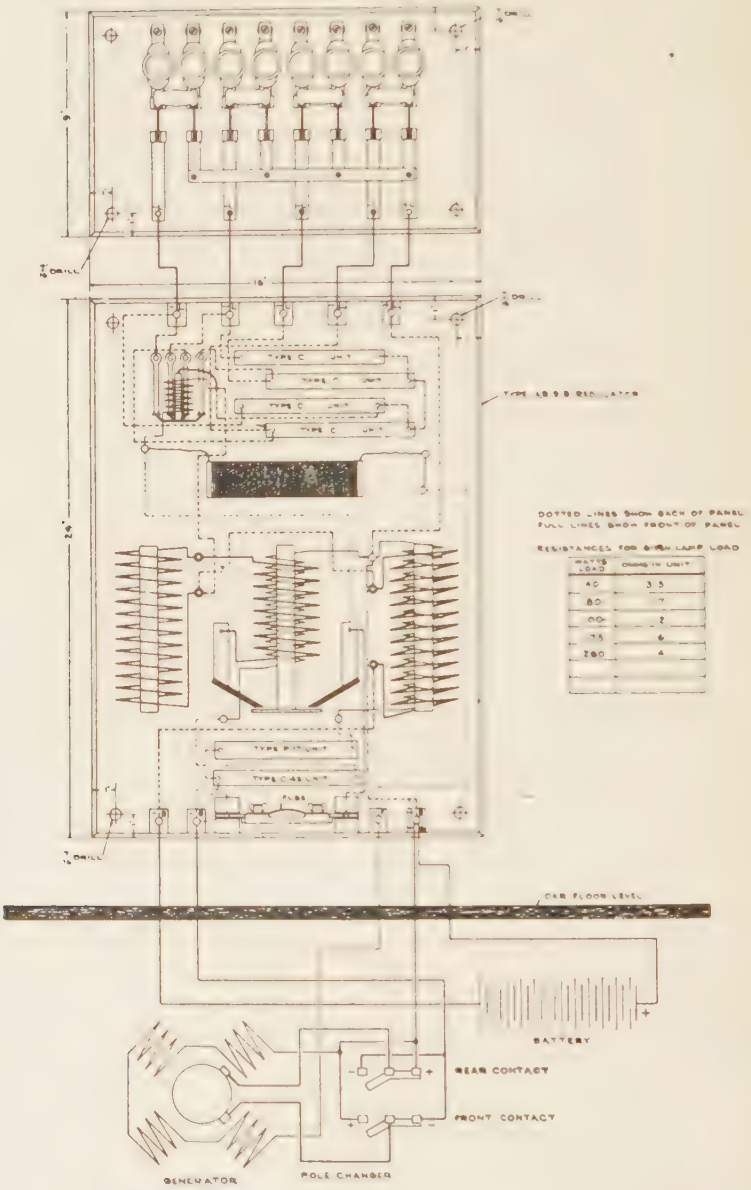


FIG. 183—Wiring Diagram of Type AB-9-B Generator Regulator and Lamp Controller Connected for Constant Generator Output and 4-Circuit Distributing Panel.

the lever *G* and the retaining washer *X* measures approximately 1⅜ in. By locking together nuts *H'* and *H''* the spring can be held in this position. Then allow lever *M* to return to its lowest position against the stop *W* and by means of the cap screws *K* and *K'*, compress the main carbon piles *U* and *U'* until full compression is on the piles, which can best be determined by observing the lever *M*, which will be caused to rise as soon as piles *U*, *U'* and *T* are fully compressed. The equalizing lever *Y* should be kept as nearly vertical as possible by dividing the adjustment between the two screws *K* and *K'*; the nuts *L* and *L'* are for locking these screws in place.

On the multiplier the stud *C* should be so adjusted as to let the lever *Z* come down to within approximately ⅝ in. from the magnet from *W'*. Enough carbon discs should be placed on the pile *V* to permit full compression of the pile by approximately ⅜ in. upward movement of the lever *Z*, and at the same time allow the pile to be entirely released when the lever is in its lowest position. The lamp voltage is raised or lowered by moving the balancing weights *Q* and *Q'* to the left or to the right respectively. This adjustment covers a range of two volts. If a further alteration of the lamp voltage is required, it may be accomplished by adding weights *R* to, or removing weights from the piston *S*. The lead weights sent out with the regulator will make an increase of approximately one volt for each weight added to the piston.

Earlier Types of Simplex Equipments. No fundamental changes have been made in principles and the main features of design since the "Simplex" car lighting equipments were introduced a good many years ago. The first equipments placed in service were identical in most respects with the latest standard equipments as already described, but a number of refinements have been introduced from time to time. As many of the older equipments are still in service, it will be well to summarize the features in which some of them differ from the present standards.

The only material change in generator construction has been the introduction of ball bearings. The present AB, GB, BB and CB generators are the same as the old sleeve bearing machines Types A, G, B, and C, except that the shafts and housings changed to accommodate ball bearings.

The early type BB Generator Regulators differed from the present BB-9-B principally in the following respects: The dash

pots were of brass instead of moulded composition, and were designed for heavy fluid instead of the light oil used in the present dash pots. The lifting coil of the automatic switch and the potential regulating solenoid were not compensated for temperature variation; but a small resistance unit was included in the potential circuit, in some cases, for the purpose of changing the voltage setting. The differential battery current winding on the potential solenoid was not used. Consequently the charging cycle ended in a long tapering off of current, while voltage was held constant at its maximum value. The plungers were attached to their levers by links.

Heat compensation of the potential regulating circuit was introduced in the BB-2 regulator, reducing the variation of potential setting with operating temperature to less than one volt. In the BB-7 regulator the lifting coil of the automatic switch is similarly heat compensated. The differential winding is added to the potential regulating solenoid, reducing the generator voltage at the end of charge, and producing a quick termination of the charge. An auxiliary winding on the current solenoid—no longer used—causes a reduction of the charging rate at high speeds. The automatic switch is provided with an additional contact at the top to cut out the current coil during discharge of the battery —no longer used. The plungers are detached from the levers and engage them by butting contact as in the latest regulators. The BB-9 regulator has moulded dash pots and the same features as the BB-9-B regulator described above, with the exception of the differential winding on the potential solenoid. The A, A-2, and A-9 regulators have the same features that have been enumerated for the BB, BB-2, and BB-9. Contact for cutting out the lamp circuit resistors is made by fingers below the automatic switch on which the main contact plate rests when the switch is open. In the AB-9-B regulator the size of certain parts is somewhat reduced. The lamp circuit resistors are cut out by a separate magnet switch; and space is provided for mounting all resistance units directly on the panel.

The type M-2 lamp regulator is the same as the original type M regulator except that temperature compensating units have been added in the circuit of the multiplier coil, and the dash pots changed to permit the use of "Dasho" fluid instead of castor oil.

CHAPTER XVIII

SAFETY CAR LIGHTING EQUIPMENT

The Safety Car Lighting Equipment consists of a generator, driven by a belt from the car axle, a generator regulator panel, a lamp regulator panel mounted in a cabinet inside or under the car body, and a storage battery which is suspended in a box under the car body.

In this system of lighting, the generator regulator comprises a combination of current and voltage control which gives a taper charge to the battery; starting the charge of a fully discharged battery the current is held constant at a value of about the full output of the generator. As the charge progresses the value of the current will be slightly decreased due to strengthening of the voltage coil as the battery voltage rises. As the counter-electromotive force of the battery rises due to its being charged, the generator voltage will automatically rise with it in order to maintain current to the battery. This continues until the voltage has risen to approximately 39 volts for lead batteries and 43 volts for Edison batteries. The voltage regulating coil then becomes the controlling factor in the regulator and holds the generator voltage constant; this voltage, however, is somewhat modified by the amount of current going through the current regulating coil. As the voltage regulating coil will not permit a further rise in voltage the amount of current which can be put through the battery decreases and when the battery is fully charged the current has decreased to a few amperes.

The lamp regulator is a device for controlling the voltage to the lamps, holding it constant between 30 and 31 volts when the battery or generator voltage is above that amount.

Generator.—The generator is a four-pole, shunt-wound machine designed to give sparkless commutation with the varying speeds and varying loads met with in car lighting. The Safety generators

are made for both body and truck suspensions. They are also made for high and low speed operation and in the following sizes: 1 kw., 2 kw., 2.6 kw., 3 kw., 4 kw. As far as possible, similar parts are made to be interchangeable among the different sized machines.

The Safety generator consists of the following main parts: magnet frame, pole pieces, field coils and retainers, armature, bearings, pole changer, brush rigging and brushes.

The magnet frame *G* is a one-piece steel casting; the supporting lugs being cast solid with the frame. The housing heads *C* which carry the bearings are made of cast iron and bolted to the magnet frame at each end. Handholes, with water and dust proof covers, are provided at the commutator end for inspection purposes. The pole pieces, *B*, are of the laminated type, bolted to the magnet frame by through bolts with nuts and lock washers.

The field coils are held in position by the pole pieces, and also by field retainers *D* which are bolted to the magnet frame by through bolts with nuts and lock washers.

The arrangement makes it impossible for the field coils to slip or wear by rubbing against the pole pieces. After being wound, the field coils are impregnated by the vacuum process with a material which makes them oil proof and water proof. The coil leads are flexible rubber covered wire soldered to the soil and securely taped six inches before coming through the insulation.

The armature, *A*, is form wound with conductors having heat proof insulation. The coils are held in the core slots by hard fiber wedges; no band wires being used except at the ends, outside of the pole pieces. The armature core is built up of transformer iron laminations, annealed and insulated after punching. They are assembled under heavy pressure between malleable iron plates at each end. Air spaces are provided in the core to secure cool running.

The commutator bars are of hard drawn copper with liberal wearing depth and ample area to carry the maximum output of the generator.

The risers, to which the armature coils are connected, are integral with the bar. The mica insulation is of the best grade amber mica, having the same rate of wear as the commutator bars.

The armature shaft is made from high-grade steel accurately

ground to size. All keys are secured to the shaft by screws, preventing any possibility of loose keys. The pulley in addition to having a tapered seat, is keyed to the shaft and locked with a castellated nut and cotter pin. The bearings for the armature shaft are annular ball bearings, of a type especially developed for this service. The bearings are either pressed on a hub which is

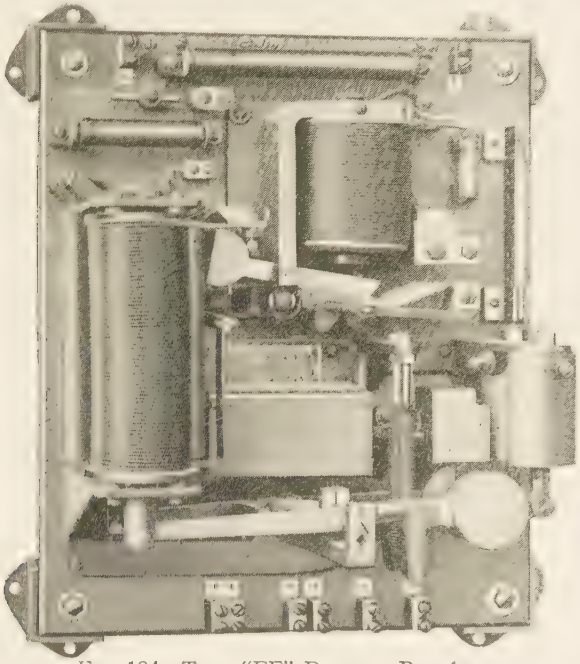


Fig. 184—Type "FF" Dynamo Regulator.

keyed to the shaft, insuring ease of application and removal, or pressed directly on the shaft where hubs are not needed.

A space is provided around the bearings for grease for lubrication. Grease grooves and felt washers prevent the entrance of dirt into the bearings and the leakage of grease into portions of the dynamo where it should not go.

The pole changer, see Fig. 27 on page 28, is of the rotating type, the direction of the current from the dynamo being kept constant by rotating the brushes through an angle of 90 degrees whenever the direction of rotation of the armature is changed.

The four aluminum brush boxes are mounted on a brush rocker

and are insulated from it by mica bushings and mica washers with large creepage surfaces. This brush rocker is mounted on a ball bearing and is free to rotate between two stops 90 degrees apart on the head. While running in one direction, the friction caused by the pressure of the brushes against the commutator holds the brush rocker against one of the stops, with the brushes in the proper position for the sparkless commutation for this direction of rotation. Reversing the direction of rotation causes the brush rocker to be turned over against the other stop, changing the position of the brushes 90 degrees. The generator then gives the same polarity, although the direction of rotation has been reversed.

The brushes are made of carbon and provided with flexible copper pigtails to give positive contact with the brush box. Each brush is provided with a separate pressure spring of such design that the pressure on the brush is constant until the brush reaches its limit of wear. These springs are spiral springs provided with a yoke so that the spring is set for the proper pressure before it is applied to the brush holder, and needs no further adjustment. Neither is there any danger of the spring being distorted in application.

Generator Regulator. The generator regulator panel, Fig. 184 —see also Fig. 33—consists of a slate panel on which are mounted the automatic switch, field rheostat or carbon pile, two solenoid coils with their respective plungers and connecting lever arms, main and field fuses, and two resistance units.

The automatic switch consists of a fine wire shunt or lifting coil and a series or "kick off" coil of heavy copper ribbon, both surrounding an iron core which forms part of the magnet frame or yoke of the switch. At the bottom is pivoted a movable iron armature to which is attached the laminated conductor of the switch. The current flowing through the lifting coil induces in the iron core a magnetic flux, the value of which varies with the amount of current flowing through the coil. At a generator voltage of 33 volts the current through the lifting coil will have produced a magnetic flux of sufficient strength to lift the movable iron armature and bring its laminated conductor into contact with a stationary brass contact block on the switch frame. These two contact surfaces are protected by secondary carbon contacts so arranged as to be easily renewable. The lifting coil is connected in series with the small resistance unit which is located to the left

of the automatic switch, and the circuit is then connected across the generator leads. The switch is set by the manufacturer to close at proper voltage, and no adjusting of the armature should be necessary.

The field rheostat or carbon pile shown at the center of the regulator panel is connected in series with the field circuit. The resistance of this carbon pile is automatically adjusted by movement of the plungers of the regulating coils. The shunt or voltage regulating coil located at the left of the regulator panel, controls a plunger whose lever arm acts directly on the carbon pile. This coil is connected in series with the large resistance unit located on the regulator panel above the automatic switch, the circuit then being connected across the generator leads. This resistance unit is so constructed that a small section of the resistance can be short circuited by a round brass rod lifted into suitable terminals.

The series regulating coil located at the left of the regulator panel in front of the voltage regulating coil is made of heavy copper ribbon through which flows the entire current output of the generator, the design being such that a current of 65 amperes, for the 2.6 kw. machines, produces sufficient magnetism to lift the plunger and regulate the production of current.

On the front or current regulating lever arm is a finger projecting in toward the panel so placed as to be directly under a similar outward projecting finger on the rear or voltage regulating arm. These two fingers are separated by about 1/64 in. when the machine is inoperative, the position of the front arm then being determined by stop on the guide lever at the top of the solenoid frame. The stop should rest on the solenoid frame at this time, the position of the rear arm being determined by the length of the field carbon pile, this length depending upon the number of discs in the carbon pile.

Movement of the rear lever arm is transmitted to the carbon pile, pressure on which is then increased or decreased, depending upon the direction of plunger movement. The front lever arm, however, is not connected directly to the carbon pile, but its movement is transmitted through two projecting fingers to the rear lever arm, and thence to the carbon pile.

The movement of the two plungers and lever arms is dampened by two air dash pots, one connected to each arm. These dash pots are located at the right side of the regulator panel below the main

fuse. In the side of each dash pot shell is drilled a small hole to permit escape of air.

The dash pot plungers are made of graphite. The dash pot shells are applied so that the vent hole points to the front, or nearly so, to facilitate inspection.

There are no adjustments to be made on the generator regulator panel other than to the field carbon pile and the short circuiting

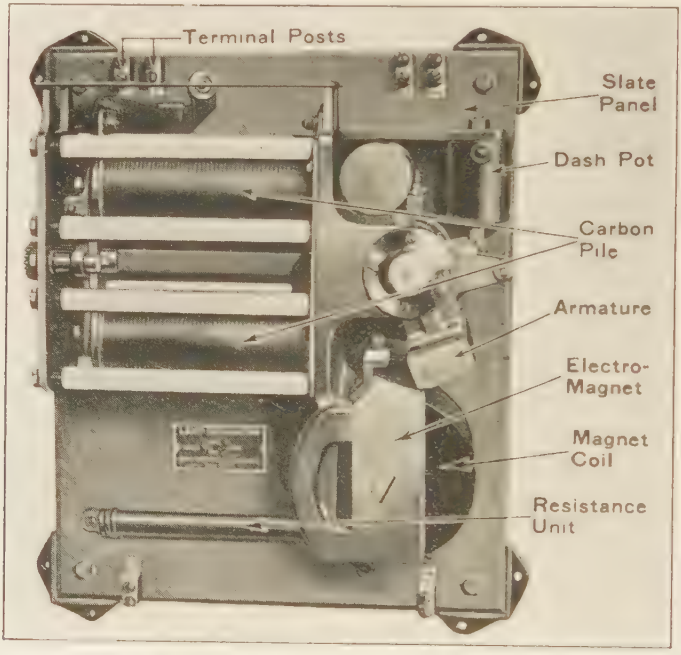


Fig. 185—Type F Lamp Regulator.

bar at the large resistance unit. The field carbon pile should contain enough carbon discs to give a separation of 1/64 in. between the fingers of the two arms when the machine is inoperative. The short-circuiting bar should be closed when a lead battery is used and open when an Edison battery is used. The springs connected to the lever arms are adjusted at the factory and therefore no adjusting is necessary.

The type FF generator regulator is an improvement on the type F regulator which has recently been improved by changing the method of transmitting the motion of the voltage coil carbon pile.

On the type F regulator, motion is transmitted directly from the lever by an arm which is cast integral with it, but the improved type, FF, motion is transmitted from the lever to the pile through a cam. With this new arrangement the generator gives its full output at considerably lower speed than with the former arrangement.

Lamp Regulator.—The Safety lamp regulator, Fig. 185, consists of two piles of carbon discs and an electro-magnet. The two carbon piles are connected in parallel and these two piles in parallel are connected in series with the lamps.

The electro-magnet automatically controls the pressure on the carbon piles. It consists of a shunt coil with an iron frame and a movable armature which is mounted on a crank block. The crank block is mounted on ball bearings and connected through a link to a pressure plate at the left end of the carbon piles, the right end plates of the carbon piles being stationary. On the left end of the link is a corrugated nut by means of which the regulator adjustments are made. The movement of the armature is opposed by a spring, located directly back of the two carbon piles, and limited at each end by a stop. The two extreme positions of the armature correspond respectively to maximum and minimum pressure on the carbon piles.

The shunt coil of the electro-magnet is connected in series with the resistance unit located at the bottom of the lamp regulator panel, and the two are then connected across the lighting circuit so that they receive the lamp voltage. The flow of current through the magnet coil induces in the iron core a magnetic flux the value of which varies with the amount of current flowing through the coil. The pull of this flux on the armature is opposed by the pull of the spring, and the design is such that the pull of the spring and the pull of the electro-magnet will balance at the desired lamp voltage, thereby holding the lamp voltage constant at that value.

When the lamp voltage is high the magnet becomes stronger and pulls the armature down against the tension of the spring and reducing the pressure upon the carbons and increasing their resistance and bringing the lamp voltage back to normal. If the lamp voltage is low the magnet becomes weakened, the spring pulls the armature back, and through the lever connection exerts

enough pressure on the carbon piles to decrease their resistance and bring the lamp voltage back to normal.

An air dash pot of the same type as used on the generator regulator is employed on the lamp regulator. All co-operating parts of the dynamo and lamp regulators are built up as units on metal frames. These frames are secured to the slate panels, but the operation of the parts is independent of the mounting on the

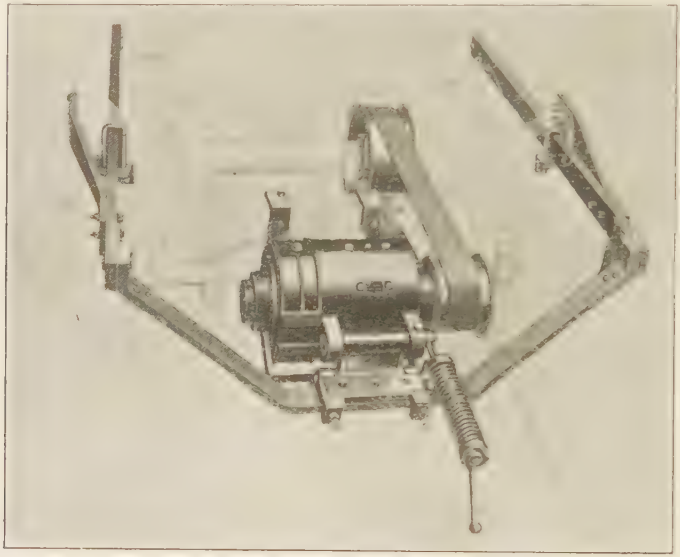


FIG. 186—Details of Truck Suspension.

slate panels. Any parts may be removed without disturbing the slate panel and all connections are accessible from the front.

Voltage coils on both dynamo and lamp regulators are compensated for change in voltage, due to heating of the coil windings, by zero heat-co-efficient resistance placed in series with the coils.

Truck Suspension.—A Safety truck suspended generator is shown in Fig. 186. The generator is mounted on the car truck outside the end sill and driven by a belt from a pulley on the car axle. Fig. 187 shows the general arrangement as applied to a standard form of a cast steel truck. The generator is mounted on a frame carried on two bars which are supported by the truck. The four generator lugs C are drilled for two supporting shafts

D, which pass through the lugs and through the solid links *A*, the links being as long as the distance between the lugs. The lower end of each link *A* is supported by a shaft which passes through the link and supporting frame *B*. The shafts are locked in the lugs and supporting frame, the turning motion being confined to the bushings in links *A* on the shafts. This design provides a parallel suspension with points of support below the generator. The most important feature of this type of suspension is that it maintains constant belt tension, even when the belt stretches six inches. A tension spring bracket is bolted to the supporting frame and the tension rod *F* is secured to the end of

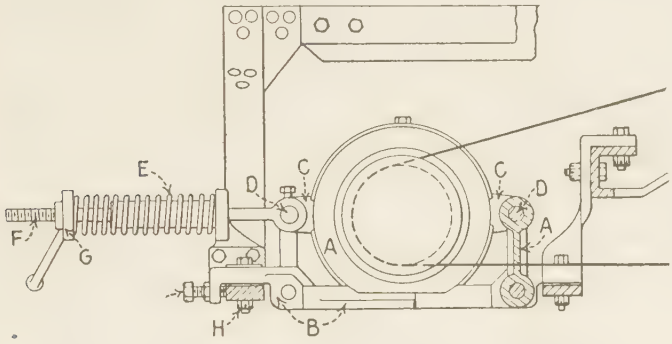


FIG. 187—Diagrammatic View of Truck Suspension.

the shaft *D* with a tension spring *E* held at a proper tension by the nut *G*.

Excessive belt strains, sometimes considered necessary to prevent the belt slipping when the tension decreases due to the belt stretching, are eliminated by this design. The nut *G* cannot be screwed beyond a predetermined position on the rod *F*, which limits the amount of tension an operator or inspector can apply. When the links *A* are in a vertical position the belt tension is due only to the pull of the spring *E*. If the belt is of such a length that the links are inclined away from the truck, a part of the weight of the generator is added to the belt tension, the amount depending upon the distance the generator is off the vertical. In moving this distance the tension spring is somewhat released and gives less pull. The design is such that the loss of tension in the spring is equal to the additional tension due to the generator

weight, and the total tension on the belt remains constant. If the links are inclined toward the truck, the weight of the generator is subtracted from the increased spring tension, and the belt tension is still maintained constant. All parts of the suspension subject to wear are lubricated grease pockets with felt washers being provided.

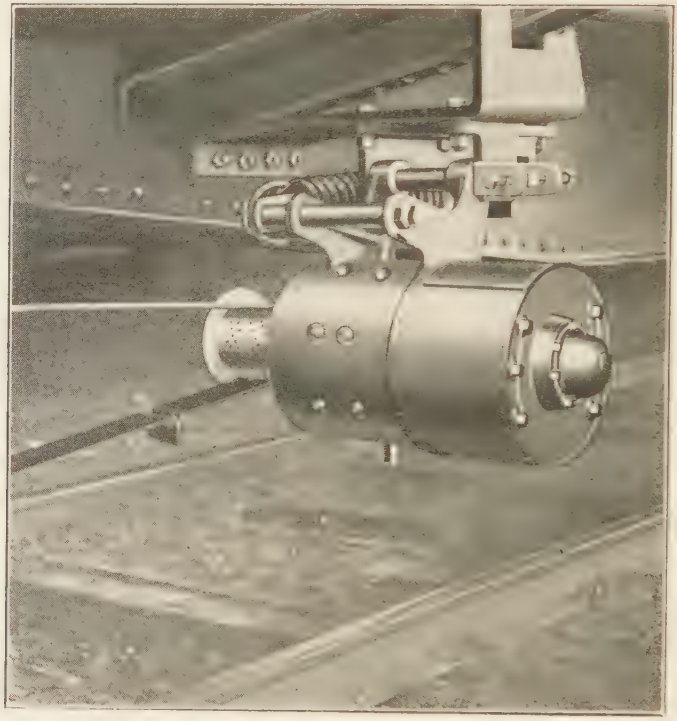


FIG. 188 Details of Suspension.

The arrangement for lining up the generator with the car axle is simple and easily operated. The supporting frame *B*, is secured to the suspension irons by six bolts *H*. The center bolt on the front side, or side farthest away from the truck, passes through a round hole in both the supporting frame and suspension iron. The holes in the supporting frame for the other five bolts are slotted so that the whole frame *B* can be swung around the center bolt. To line up the generator, it is only necessary to loosen up

all the bolts, line up the machine by means of the two adjusting bolts *I*, and lock it securely in position by means of the bolts *H*.

Inspection of the dynamo or removal of pulley, armature, or heads whenever necessary is facilitated by the absence of long supporting bars giving clear space around the generator.

In the illustration, it can be also noted that one side of the suspension is supported by a cross member fastened to side irons extending from the truck ends, while the other side is held by a bracket bolted directly to the end sill. This is a good arrangement, since the weight of the generator is distributed between the truck and side irons instead of having all the weight of the generator carried by the side irons.

Underframe Suspension.—A Safety generator and underframe suspension is shown in Fig. 188. The generator lugs are pivoted to the suspension lugs *B* on the suspension casting by the shaft *C*. The suspension casting is bolted to a plate which is secured to the car underframe. The tension on the belt is applied by the weight of the generator and by the tension spring *D*, which engages at one end with lug *A* on the generator frame, and at the other end with the bracket *F*, fastened to the suspension casting. The parts are so designed that the sum of these two varying factors is constant. When the generator is hanging so that its center of gravity is directly under the supporting bar *C* the weight adds nothing to the belt tension but the spring *D* has its greatest effect, since the leverage on which the spring acts is greatest. If the generator is swung toward the truck the weight of the generator is giving tension, but the pull of the spring is decreased as the leverage is shortened; the sum of the two tensions being the same as in the first position. Ample latitude is provided between the two extreme positions of the generator to take care of belt stretch and the variation in distance between the generator and axle when the car is on a curved track.

The tension spring *D* is assembled on a carrier, under the proper tension, so that to apply it to the suspension it is only necessary to slip the two pins through the holes in the carrier and corresponding holes in generator lug *A* and in the bracket *F*.

Operation.—Fig. 189 is a wiring diagram of the Safety Type F equipment and the operation is as follows:

When the car is standing and generator inoperative the current

to the lamps is furnished by the storage battery. When the car is in motion the generator voltage will build up due to the residual magnetism of the field pole pieces. At slow speeds there is generated in the armature a low voltage which forces a small amount

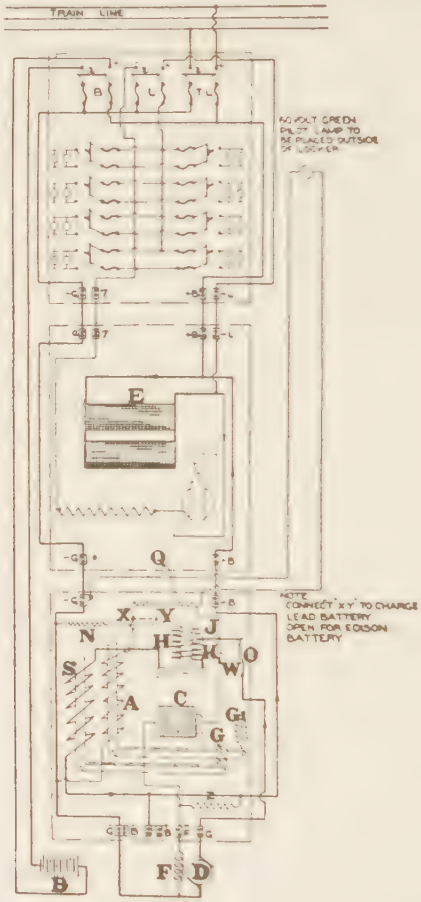


Fig. 189—Wiring Diagram of 40-Volt Type "FF" Regulators.

of current through three parallel circuits, comprising the lifting coil *J* of the automatic switch, the field circuit, and the voltage regulating coil *A*.

As the speed of the armature increases and the current in the field circuit increases the field magnetic strength, the generator

voltage also increases until it reaches 33 volts, at which time the automatic switch *H* should close and connect the generator to the car wiring.

The instant the automatic switch *H* closes, all circuits become energized, the generator furnishing current for any lamps that may be turned on, but delivering only a small amount of current to the battery. As the speed increases the generator voltage rises and increases the battery charging current until the generator output reaches a value of 65 amperes for the 2.6 kw. equipment. Assuming the battery to be in a discharged condition, the generator voltage will now be about 35 to 38. The flow of this 65 amperes or total generator current through the series regulating coil *S* magnetizes the plunger of this solenoid and any increase in current above 65 amperes produces a magnetism of sufficient strength to lift the plunger and its lever arm, which movement is transmitted through the rear lever arm to the carbon pile *C*, increasing the resistance of this carbon pile and reducing the field magnetism until the current falls to its normal value of 65 amperes.

From the instant the generator starts to build up, the voltage regulating coil *A* is alive but the current through it is not sufficient to produce the magnetism necessary to lift its plunger. This current in the voltage coil, however, is sufficient to produce some pull against the regulating springs and in this way reduces the current output. The generator voltage gradually increases as the batteries become more fully charged, and this rise in voltage effects a corresponding gradual increase in the current through the coil, until the battery is fully charged, when the generator voltage will be about 39 volts for a lead battery and 43 volts for an Edison battery. The current through the voltage regulating coil *A* will then produce a sufficient magnetism to raise the plunger and decrease the pressure on the field carbon pile *C*, thus increasing the resistance of the field circuit, which reduces the magnetism in the pole pieces. Any tendency toward further rise in generator voltage is met by a further lifting of the shunt coil plunger so that the maximum voltage obtainable, when a lead battery is used, is 39 volts.

As the machine continues to operate after the batteries have been fully charged the voltage will remain constant at 39 and the

current will gradually taper as the counter e. m. f. of the battery increases.

The voltage limit of 39 is for a lead battery. When Edison batteries are used a voltage of 43 is required for a full charge. This increase in regulated voltage is obtained by increasing the resistance of the voltage regulating coil circuit. To do this it is only necessary to slide the small brass rod XY to the left. This

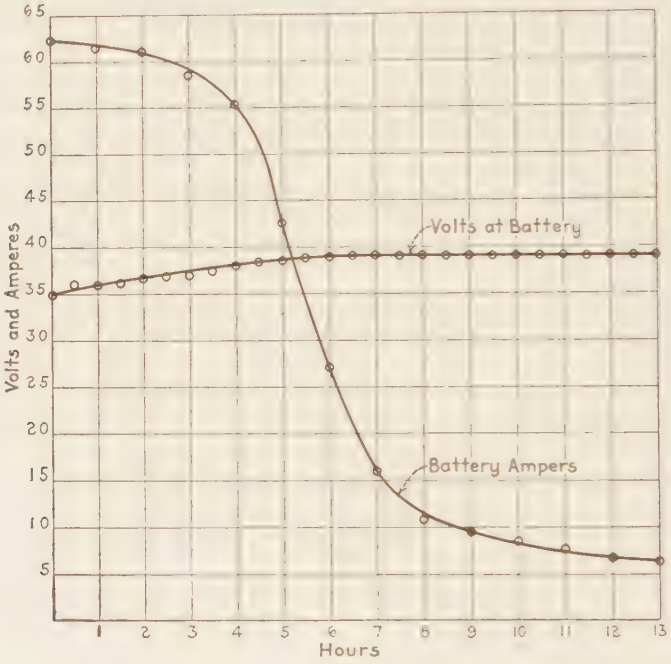


Fig. 190—Battery Charging Curve With Type "F" Dynamo Regulator.

removes the short circuit from a section of the resistance unit Q. By increasing the resistance of the voltage regulating coil circuit in this manner the current in the circuit will not produce sufficient magnetism to lift the plunger and decrease the carbon pile pressure until the generator voltage has reached 43. The brass rod should be bridged across a section of the Q unit when a lead battery is used and should be disconnected when an Edison battery is used.

Fig. 190 is a lead battery charging curve of a Type F dynamo

regulator. The regulation is current modified by voltage, followed by voltage modified by current.

Operation of the Lamp Regulator.—Referring to the wiring diagram Fig. 189 it may be noted that the current to the lamps from the battery or generator passes through the two carbon piles *E* which are connected in parallel. It may also be noted that the regulator coil circuit is connected across the lamp circuit on the load side of the carbon piles *E*. Therefore the rheostat effect of the carbon piles governs both the lamps and the operating circuit

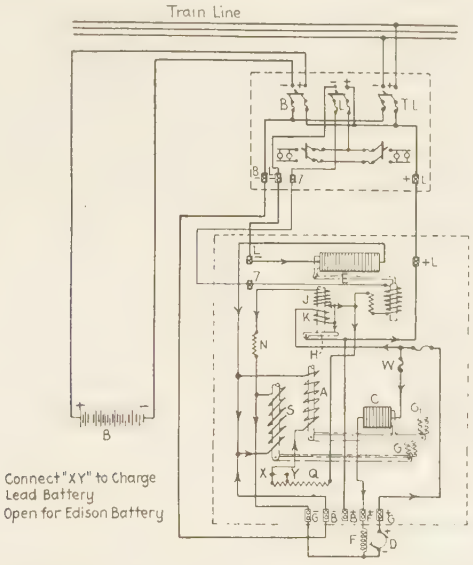


Fig. 191—Wiring Diagram for Type "F-1" Dynamo and Lamp Regulator.

of the regulator. Assume that the lamp regulator is adjusted for a lamp voltage of 30 volts. A sudden increase in speed will momentarily subject the lamp circuit to a higher voltage, but the same high voltage is impressed upon the operating coil, forcing increased current through this circuit, which action results in sufficient increase in magnetism to pull the armature of the regulating magnet down to the left and decrease the pressure on the carbon piles *E*. As this pressure is decreased, the voltage drop in the piles increases, with resultant reduction in lamp voltages. Therefore the voltage on the coil decreases with the lamp voltage,

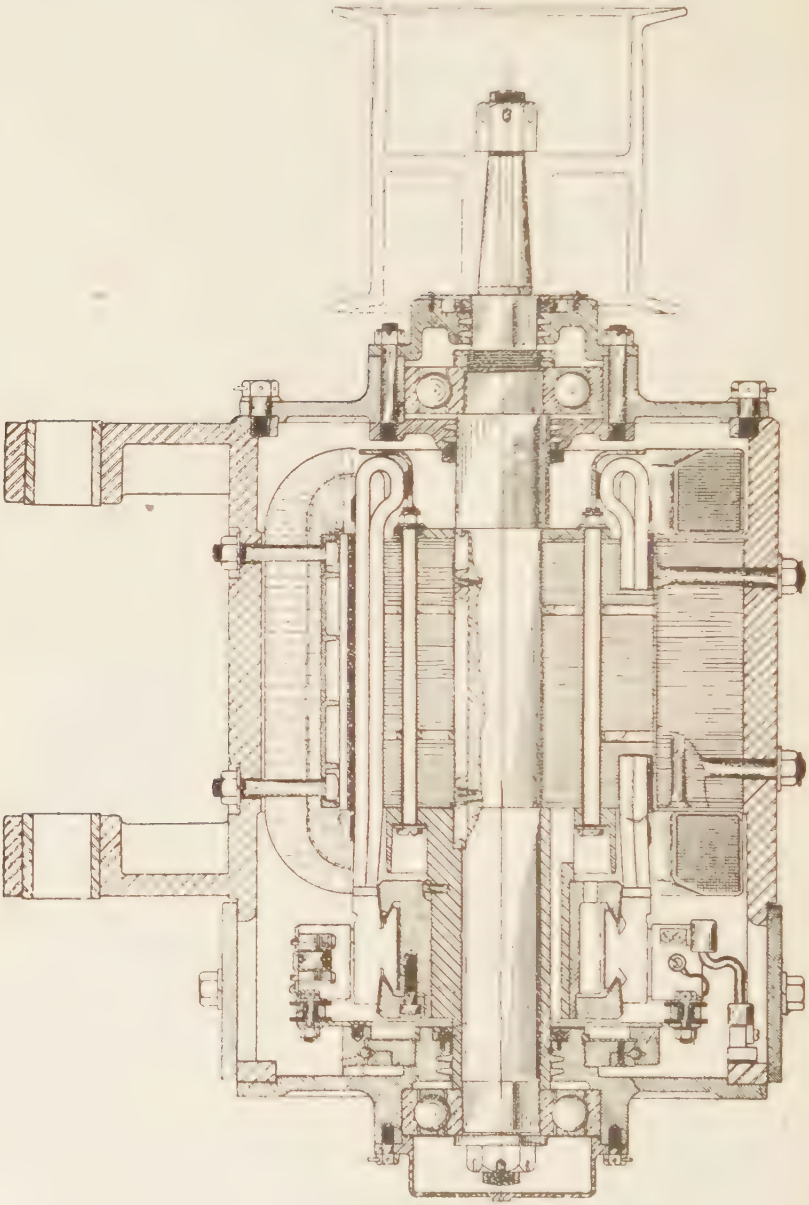


FIG. 192—Type F-2 Safety Generator.

which effects a reduction in the coil current and magnetism until the voltage is reduced to 30 volts. When this has taken place the pull of the magnet and opposing spring will balance and no further movement will occur until there is a further change in voltage.

If the lamp voltage drops below normal, the reverse action takes place. The spring then exerts the stronger force and pulls the armature to the right, increasing the pressure in the carbon piles *E*. This reduces the voltage drop in the piles and increases

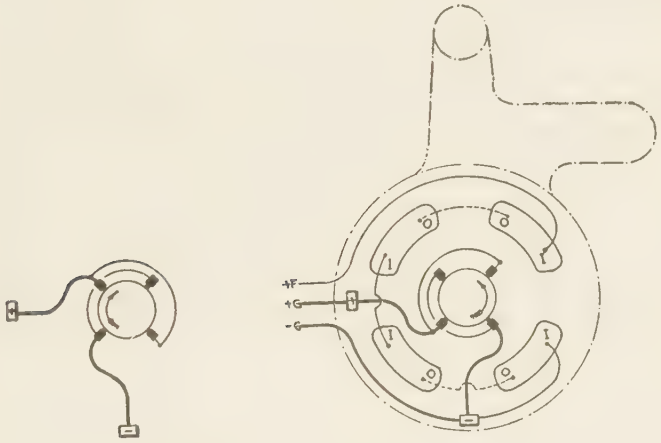


FIG. 193—Diagram of Field Coil Connections.

the voltage on the lamps and the coil until the magnetic pull again balances the pull of the spring.

Safety F-1 Regulator.—The Safety F-1 regulator has been designed for use on cars having small loads. Its operation is practically the same as the Type F, just described. Both lamp and generator regulator are mounted on the same panel. The wiring diagram of the F-1 equipment is shown in Fig. 191.

Safety F R Equipment.—The Safety F R equipment is designed for non-passenger carrying cars, where the question of close lamp regulation is not regarded as an essential. Instead of a variable resistance in the lamp circuit, fixed resistances are used. These resistances are in series with the lamps when the dynamo is charging the battery, and short circuited when the lamps are lighted from the battery. The change is effected by a contactor

operated by the main switch. The dynamo regulator is the F-1 with the exception that the main switch is of the solenoid type.

The Safety Type F2 equipment is a modification of the Type F equipment, designed to meet the Pennsylvania Railroad specifica-

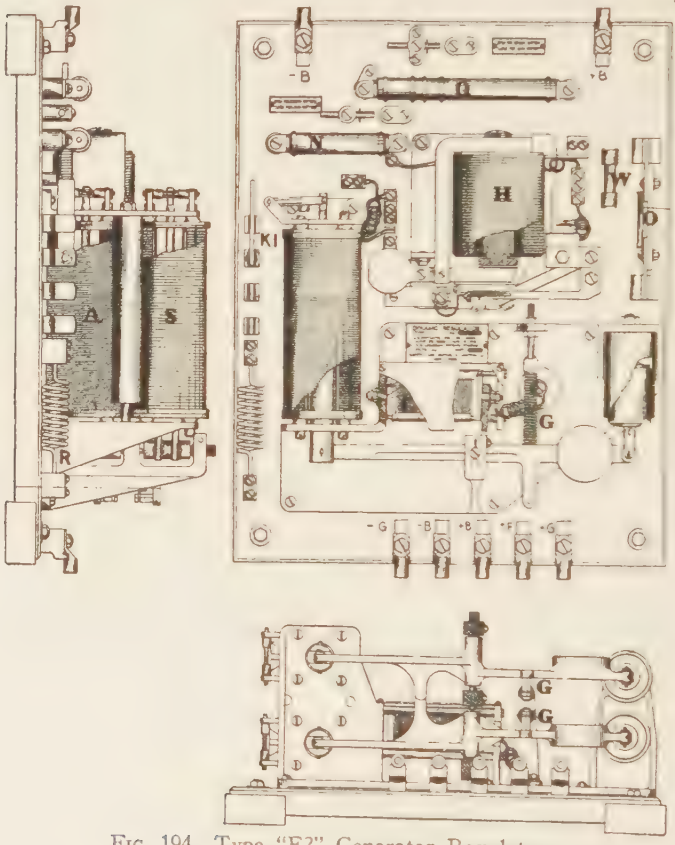


Fig. 194—Type "F2" Generator Regulator.

tions for car lighting. The Type F2 equipment is also used on other roads.

The Generator.—The generator, Fig. 192, is a four-pole, shunt-wound machine, rated at 2 kw. at 40 volts and representing a generator capacity of 50 amperes. The four laminated pole shoes with their field coil retainers are fastened to the magnet frame by

through bolts with lock washers and nuts. The cast-iron heads of the generator, which supports the bearings, are bolted to the ends of the magnet frame. Ball bearings are employed on both the pulley and commutator ends of the shaft, and are lubricated by grease which is enclosed in the heads.

The pole changer is of the rotating type. The friction of the brushes is sufficient to cause the pole changer to revolve through an angle of 90 degrees when the direction of the car motion is reversed; the travel of the pole changer is limited by stops.

Three wires—positive generator, negative generator, and positive field—are brought out through the bushed holes in the generator frame and connect to corresponding terminals on the generator regulator panel. The negative field is connected directly to the negative generator lead inside of the generator frame, as shown in diagram, Fig. 193.

The F2 generator has a cutting-in speed of 250 r.p.m. and a full load speed of 333 r.p.m. On a car equipped with 36-in. wheels and an 18 to 8 reduction; that is, 18-in. axle pulley and 8-in. armature pulley, this generator will cut in at a train speed of 12 miles per hour and carry full load at a train speed of 15.9 miles per hour. It will also operate safely at a train speed of 75 miles per hour with wheels worn to the limit. Therefore, this equipment is suitable for either branch line service where the train speeds are low or main line service where speeds are higher.

The F2 armature weighs 215 lb.; the generator, less pulley, 775 lb., and the total weight of generator and suspension complete is 1,075 lb.

Generator Regulator.—The generator regulator, Fig. 194, is rated at 40 volts, 41 amperes, and consists of a slate panel on which are mounted the automatic switch *H*, field rheostat or carbon pile *C*, voltage regulating coil *A* and current regulating coil *S*, with their respective plungers and lever arms, 65 ampere main, and 10 ampere field fuses *O* and *W*, respectively, two resistance units *Q* and *N*, a knife switch *K*-1, and a special resistance coil *R*. The automatic switch *H* consists of a fine wire shunt, or lifting coil and a series, or "kick off" coil of heavy copper ribbon, both surrounding an iron core which forms part of the magnet frame or yoke of the switch. At the bottom is pivoted a movable iron armature to which is attached the laminated con-

ductor of the switch. The two contact surfaces of the switch are protected by secondary carbon contacts so arranged as to be easily renewable.

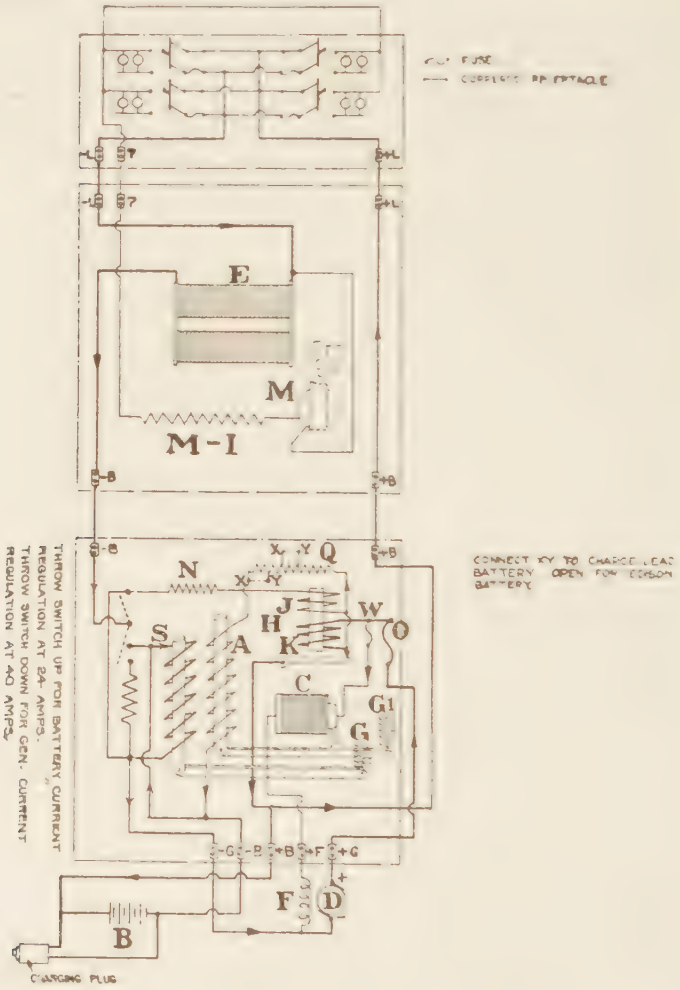


FIG. 195—Wiring Diagram Type "F2" Equipment.

Referring to the wiring diagram, Fig. 195, note that the lifting coil *J* is connected directly across the generator terminals, while the series coil *K* is connected directly in the generator circuit. The

series coil is known as the "kick off" coil on account of its action. When the generator voltage falls below that of the battery, a reverse current will flow back through this coil from battery to generator. This current will generate a magnetic flux which will oppose the shunt coil magnetism, and when these two forces balance, the switch is opened by the force of gravity. The *N* unit connected in the lifting coil circuit has a resistance of 45 ohms.

The field rheostat or carbon pile *C*, Fig. 195, is connected in series with the field circuit. It is 2⅝ in. long and contains approximately 168 discs, which are 1/64 in. thick and 1⅞ in. in diameter. The resistance of this pile is automatically adjusted by movement of the plungers of the regulating coils. The shunt or voltage regulating coil *A* is connected directly across the generator terminals. The series regulating coil *S* is made of heavy copper ribbon and is connected in series with the main circuit.

The knife-switch, *K*-1, Fig. 194, is used in changing the control from 24 to 41 amperes or vice versa.

The resistance unit *Q*, located above the automatic switch, has resistance of 16.3 ohms, with tap at 14 ohms. It is connected in the voltage regulating coil circuit. This unit is so constructed that a small section of the resistance *XY* can be short-circuited by a round brass rod fitted into suitable terminals.

The pull of the regulating coils upon their respective plungers and lever arms is opposed by the pull of the two small spiral springs, *G* and *G*-1. The spiral springs are approximately ½ in. in diameter and 2 in. long. Spring *G*-1 is connected to the voltage regulating coil lever arm, and spring *G* to the current regulating coil lever arm.

The upper end of spring *G*-1 is attached to a pin provided with three small slots. The regulated voltage control may be changed by moving the spring from one slot to another.

Lamp Regulator.—The lamp regulator, Fig. 196, is rated at 40 volts, 50 amperes and consists of a slate panel upon which are mounted two carbon piles *E*, electric magnet *M*, and resistance unit *M*-1. Each carbon pile is approximately 6 in. long and contains 48 discs ⅛ in. thick and 2⅝ in. in diameter. The two carbon piles are connected in parallel with each other and in series with the lamps. See Fig. 4. The electro magnet *M* automatically controls the pressure on the carbon piles. The design and oper-

ation of the F2 lamp regulator is the same as that for the Type F lamp regulator which was described in the previous articles.

Suspension. The Type F2 Safety generator is suspended from the car body. The Safety or P. R. R. constant belt tension devices are used with this equipment.

Storage Battery. The storage battery used with the Type F2 Safety equipment consists of 25 Type A-4-H Edison cells. This battery is assembled in five trays, five cells per tray, and has a capacity of 150 ampere hours.

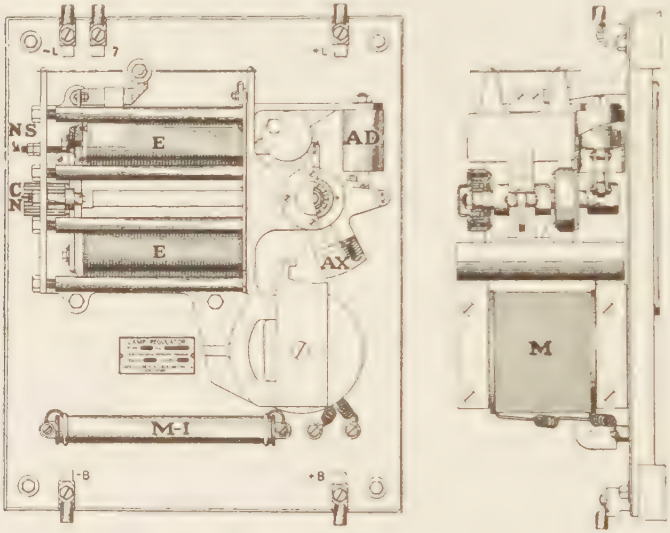


FIG. 196—Type "F2" Lamp Regulator.

The lead storage battery may also be used with this equipment.

Operation. Fig. 195 is a wiring diagram of the Type F2 Safety equipment and the operation is as follows:

When the car is standing and the generator inoperative, the current to the lamps is furnished by the storage battery *B*. When the car is in motion, the generator voltage will build up due to the residual magnetism of the field pole pieces. At slow speeds there is generated in the armature a low voltage which forces a small amount of current through three parallel circuits—the lifting coil *J* of the automatic switch, the field circuit *F*, and the voltage regulating coil *A*.

As the field of the armature is increased, and the current in the

field circuit increases the field magnetism strength, the generator voltage also increases until it reaches 33 volts, at which time the automatic switch *H* should close and connect the generator to the car wiring.

The instant the automatic switch closes all circuits become energized, the machine furnishing the current for any lamps that may be turned on, but delivering only a small amount of current to the battery. As the speed increases the generator voltage

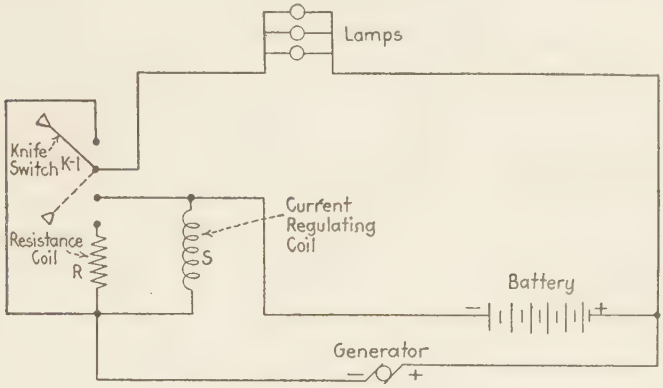


FIG. 197—Schematic Wiring Diagram of Main Circuits, Knife Switch Up for 24 Ampere Battery Charge; Knife Switch Down for 41 Ampere Generator Current.

rises, and the generator current increases until the current and voltage regulating devices go into operation.

The generator regulator is what is known as the combination current and voltage type. The charge is constant current modified by voltage until the battery is partly charged, and then voltage modified by current. The latter produces a taper charge which decreases until the current is of a low value.

In addition to this, the regulator is designed so that it will either limit the battery charging current to 24 amperes independently of the lamp load or limit the total generator output to 41 amperes.

With the first method, known as "constant battery charging current with voltage control," 24 amperes will flow to the battery, providing the voltage coil does not come into action, and all lamp current will simply be added to the generator load without affecting the amount of charging current. With the second method,

"full generator output," a useful current of 41 amperes will be available, either for lamps, battery, or both. The change from one method of operation to the other is made by throwing the knife switch, *K*-1. The schematic diagram, Fig. 197, shows how the change in control is made.

When switch *K*-1 is up, the series coil *S* controls the battery charging current at 24 amperes. The lamp load is picked up by the generator because the negative lamp tap is made on the generator side of the series coil *S*, which means that no lamp current

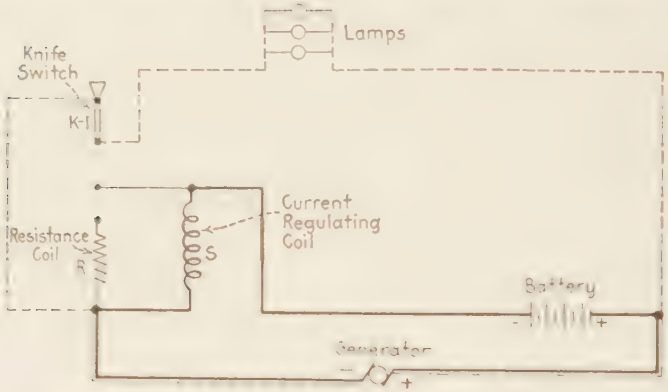


FIG. 198—Schematic Wiring Diagram of Main Circuits. Knife Switch Up for Constant Current of 24 Amperes to Battery. Heavy Line Shows Path of Charging Current from the Generator Through Battery and Current Regulating Coil, Back to Generator. The Path of the Lamp Current is Shown By Dotted Lines. Note that the Lamp Current is Direct From Generator to Lamps and Does Not Pass Through the Current Regulating Coil.

flows through that coil. This is further illustrated in Fig. 198. The path of the lamp current is shown by dotted lines, while that of the battery is shown by heavy lines.

When the knife-switch *K*-1 is down, as shown in Fig. 199, the negative side of the lamps is connected to the top of the coil *S* so that both lamp and battery current flows through the coil. But the knife switch *K*-1 now also connects resistance *R* in parallel with the coil *S*, and this resistance is so designed that it allows a current of 17 amperes to shunt by the coil when 24 amperes are flowing through the coil itself. Therefore, the cur-

rent which may flow through the multiple circuit of the series coil *S* and resistance coil *R* (sum of lamp and battery current) is now 41 amperes instead of 24 amperes, as is the case when the coil acts alone. This means that the maximum generator output, with knife-switch *K*-1 down, is 41 amperes, which is divided between battery and lamps, according to the number of lamps turned on and the battery condition. If all lamps are turned off, the entire generator output of 41 amperes is available for battery

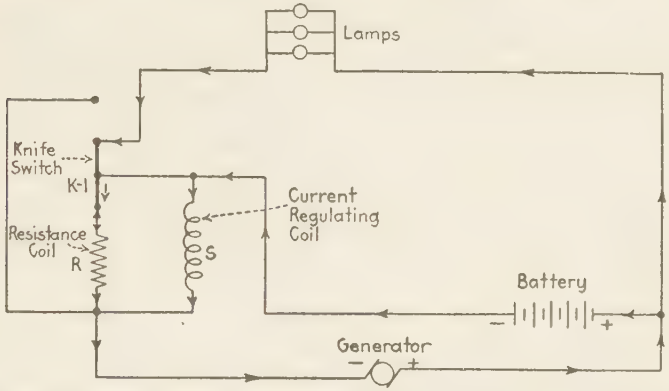


FIG. 199—Schematic Wiring Diagram of Main Circuits. Knife Switch in Down Position Generator Current Regulated to 41 Amperes and Current to Battery and Lamps is Shown by Arrows.

charging. This adjustment allows an extra heavy charging current in the winter and at other times when it is needed.

So far we have considered the current regulating feature of the generator regulator, which may be summed up as follows:

Knife-switch K-1 in up position.—The generator current will be the battery charging current of 24 amperes plus the lamp load. If the lamps are turned off, the total generator useful current will be 24 amperes. If the lamps are turned on and the lamp load is 17 amperes, the total generator useful current will be 24 ampere battery charge plus 17 ampere lamp load, or 41 amperes.

Knife-switch K-1 in down position.—The generator useful current will be 41 amperes. If the lights are turned off, the battery will receive a charging current of 41 amperes. If the lamps are turned on and the lamp load is 17 amperes, the total useful generator current will be 41 amperes, but the battery will receive the

total generator useful current of 41 amperes, less the lamp load of 17 amperes, or 24 amperes.

This current regulation is only effective up to the point where the battery is fully charged and then the change is made from current to voltage regulation and the current to the battery will gradually taper to approximately 10 amperes.

The point of change from current to voltage regulation is governed by the setting of the voltage regulating coil *A*. If this coil is set to operate at 40 volts, the voltage coil will go into operation and hold the generator voltage constant at that amount.

The voltage regulating coil on the Type F2 generator regulator has two settings. As stated above, the *A* unit is provided with a short-circuiting device, which shunts out section *XY* of the unit. It was also stated that the upper end of the spring *G*-1 was attached to a slotted pin. This pin has three slots and the end of the spring may easily be placed in any one of the three slots.

When this equipment is used with the Type A-4-H 150 A. H. Edison battery, the short-circuiting device of the *Q* unit should be open, and closed when used with the lead battery.

The voltage setting when used with lead battery is 39 volts. This is made by closing the short-circuiting device and placing the spring *G*-1 in the top notch of the pin.

The voltage setting when used with the 150 ampere hour Edison battery is governed by the season of the year. The setting for summer is 43 volts, which is obtained by opening the short-circuiting device and placing the spring *G*-1 in the bottom notch.

The setting for spring or fall is changed to 45 volts by simply moving the spring *G*-1 to the middle notch; for winter it is changed to 47 volts by moving the spring to the top notch.

At this point the fact should be emphasized that these voltage settings are effective and that the control is changed from current to voltage at these respective voltages regardless of the position of the knife-switch *K*-1.

It is interesting to note that the normal charging rate of the Edison A-4-H battery is 30 amperes, and the regulated charging current, with the knife-switch *K*-1 up, is only 24 amperes, which is entirely satisfactory for this service.

Adjustments.—The automatic switch is set by the manufacturer to close at 33 volts. No adjustment in service should be neces-

sary, but if it is found necessary to make an adjustment, this should be made at the stop at the left of the hinge pin; raising the stop makes the generator cut in at a higher voltage, and lowering it makes it cut in at a lower voltage. The position of the iron core should not be changed to make any adjustment, since, when properly set, the bottom of the core, contact block and top carbon block are all on the same horizontal line. This is necessary in order to insure that the copper brush will be drawn up solid so as to make a good wiping contact.

Generator Voltage Regulating Coil.—The adjustment of this coil is set at the factory so that it regulates at 39 volts with lead batteries. When Edison batteries are used this voltage is raised to 43 volts by opening the short-circuiting device and 45 or 47 volts by moving the spring *G*-1 to their respective slots as just explained.

In order to check the setting of this voltage coil *A*, first be sure that no current is passing through the current coil *S*. This can be done by placing a sheet of insulating material between the contacts of the main switch, then no current is passing through the current coil, and the stop on its plunger rests against the top of the coil head. With the above conditions, the car running at a speed of 15 miles an hour or more, the voltage across the generator terminals on the regulator should be as given in the preceding paragraph. If the voltage is not correct it should be adjusted by the spring *G*-1. To check the setting of the current coil *S* connect an ammeter in the generator circuit. If the stop on the plunger guide of this current coil *S* is raised from the coil head, the coil is regulating and the ammeter will show at what current the coil is regulating. If the stop is against the coil head, compress the field carbons by hand through the voltage coil lever, and note the current at which the series coil plunger begins to rise. This is the current at which it will regulate, and should be within the rating of the dynamo.

The number of field carbons should be such that, when the car is standing, and the carbons are tightly compressed by the spring of the voltage solenoid, it is possible to slip a gage 1/64 in. thick between the projections on the levers of the voltage coil and series coil.

Lamp Regulator. -To adjust the lamp regulator it is first necessary to get rid of all magnetism in the operating magnet, which

can be accomplished by disconnecting the battery. Next, remove the air dash pot *AD*, Fig. 196, using special care not to injure the graphite plunger; let the plunger hang loose on the arm and short circuit the two terminals marked *L* and *B* at the upper and lower left hand corners of the board, respectively. A piece of No. 12 copper wire makes a convenient jumper for short circuiting the two terminals. Next, unscrew the corrugated adjustment nut *CN*, Fig. 196, until the armature *AX* can be moved

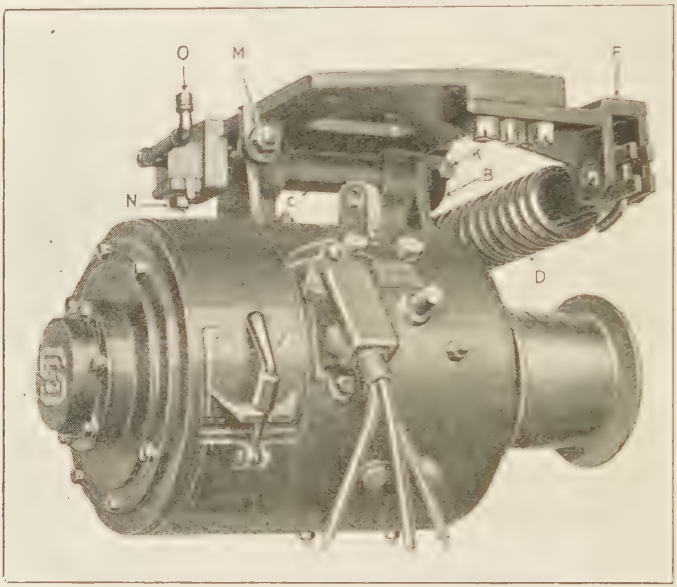


Fig. 200—Special Generator for Pullman Equipment.

smoothly throughout its full arc of travel, then screw up very slowly on the adjusting nut *CN* until the armature *AX* will not quite go back against the top stop, after which the adjusting nut *CN* should again be unscrewed one-half turn and locked in this position by means of the clamping screw. The armature can now be moved through its complete arc of travel. To adjust the spring tension it is first necessary to get current on the panel and through the lamps, but without removing the short-circuiting jumper from the two terminals on the board. Then, with a voltmeter connected to the two mains of the lamp circuit, turn on or off the lamps

until the instrument indicates 30 volts, at which time the tension of the spring should be so adjusted by nut *NS* that the armature will remain in any position throughout its stroke. It is important to maintain 30 volts at the lamps while adjusting the spring.

Next, remove the short-circuiting jumper, replace the dash pot, and note the lamp voltage as indicated on the voltmeter. If the

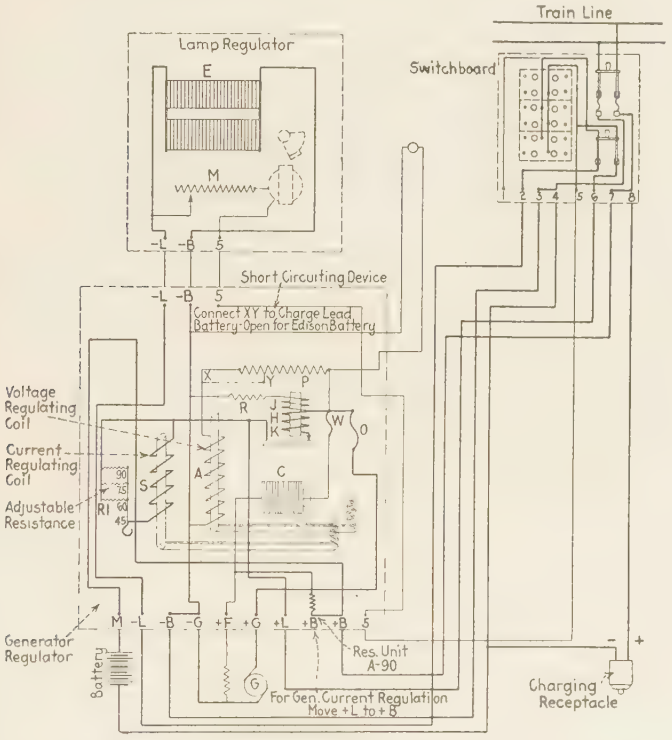


FIG. 201—Wiring diagram of Type "F" Safety Equipment for the Pullman Company.

drop across the carbon pile exceeds two volts, the carbons should be removed and the dust blown off the discs. If this does not reduce the drop, tighten up one or two notches on the adjusting nut *CN*. Next turn on all lamps and put the car on charge to obtain high voltage, and note the lamp voltage as indicated by the voltmeter. If it exceeds 32 volts the setting is incorrect and must

be done over, or there is some defect in the regulator which should be corrected.

Special Type F for Pullman Company. The Type F Safety equipment for the Pullman Company was designed to meet with the Pullman specifications. It consists of a 4-kw. underframe generator, a generator regulator rated at 40 volts 100 amperes, a lamp regulator rated at 40 volts 50 amperes, and a storage battery. This generator is shown in Fig. 200.

The general principle of operation is the same as that of the standard Type F equipment previously described, but the terminals on the regulators do not have the same location. It may also be noted by referring to the wiring diagram, Fig. 201, the addition of an adjustable resistance *R*, connected in multiple with the current regulating coil *S*. This adjustable resistance is provided with a sliding rod which shunts out sections of the resistance thereby changing the value of the current regulation to 45, 60, 75, or 90 amperes as desired. A 90-ohm. exciter unit has also been added, and located on the generator regulator panel.

The current regulation may be "current to battery," or "total generator current," depending upon the location of the lamp wire at the bottom of the generator regulator panel. The wire is connected to the $+L$ terminal for "battery current regulation," and to $+B$ terminal for "total generator current regulation."

Space and connections have been provided on the front of the generator regulator panel for the mounting of an ampere-hour meter.

The Pullman Company also use the type FF regulator which is shown in Fig. 184. This regulator is similar to the type F, also used by the Pullman Company, except that no ampere hour meter is used with it and the resistance in series with the voltage coil is a fixed instead of an adjustable resistance. This resistance is supplied with a tap so that the regulator can be used with either lead or Edison batteries.

CHAPTER XIX

STONE-FRANKLIN CAR LIGHTING EQUIPMENT

The fundamental principle of the Stone-Franklin system is a modified watt control of the battery charge which results in a straight-line charge through the whole of the charging cycle, followed by a period in which the battery charging rate is reduced within a safe limit. The battery charging rate is reduced when the counter-electro-motive force of the battery reaches its maximum value with 1 1/3 normal rate of charging current flowing through the battery.

The modified watt control of the battery charge is nothing more than a combination of battery voltage plus battery current control. For example, starting with a fully discharged battery, assume that the generator is delivering to the battery a charging current that is held constant at first at 45 amperes. The counter-electromotive force at the battery increases as the battery charges and accordingly the generator output changes quantitatively, the current tapering as the back e. m. f. of battery rises. As the charge proceeds, the generator voltage increases sufficiently to compensate for the gradually increasing battery e. m. f., but owing to the watt control of generator output the charge rate slowly tapers and the increase of battery voltage is therefore held within definite limits. This increase of battery and generator voltage continues until the generator voltage has risen to approximately 39 volts for a lead battery; then the combined effect of the 39 volts and the then prevailing charging amperes automatically reduces the battery charging rate to within safe limits, slightly below normal rate.

This action of reducing the battery charging rate after a certain state of battery charge has been reached, assists the regulation of the lamp voltage by eliminating excessive generator and battery voltages.

The Stone-Franklin equipment consists of a generator, driven

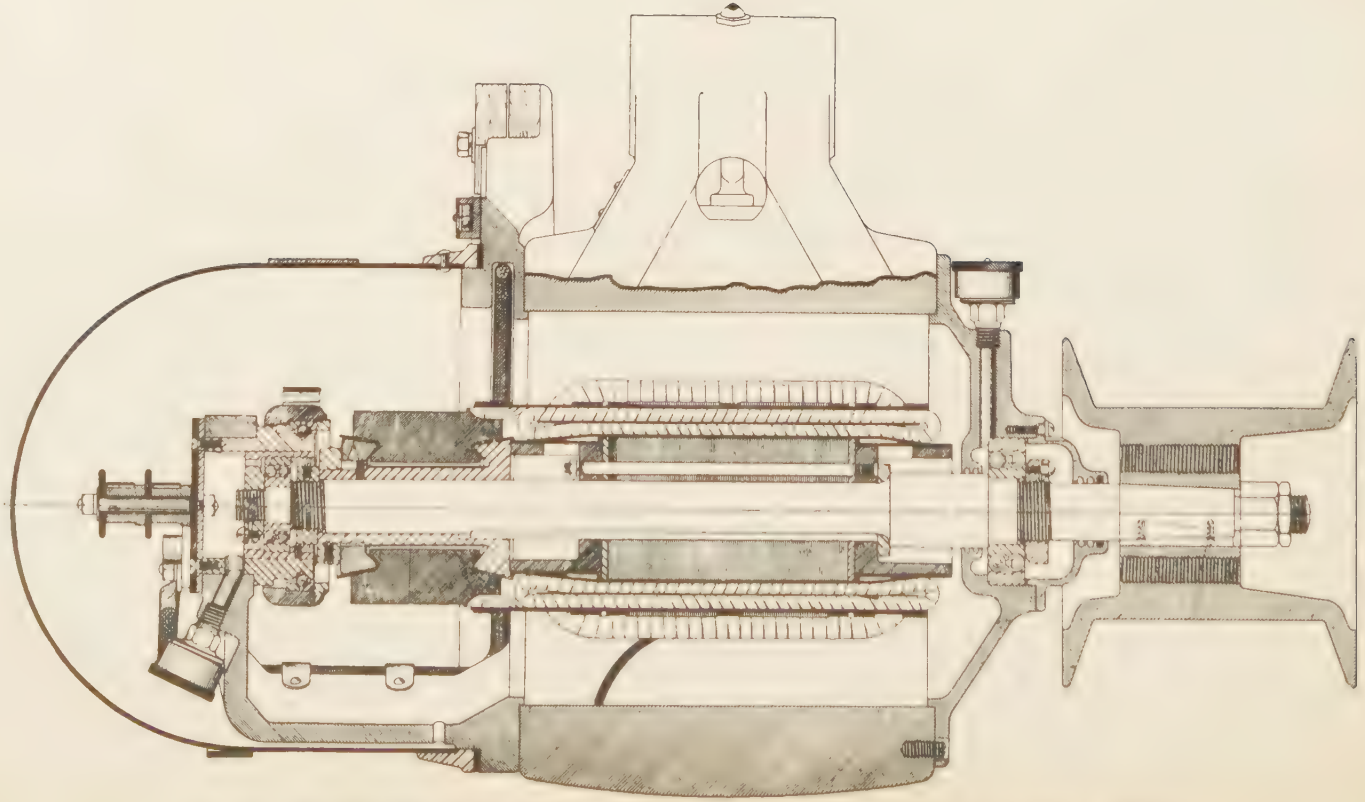


FIG. 203- Cross Sectional View of the Stone Franklin Type "T 35," 40 Volt, 40 Ampere, Generator.

by a belt from the car axle; an automatic panel, and main light panel board, mounted in a cabinet inside of the car; and a storage battery which is suspended in a box under the car body.

Generator.—The generator, shown in Figs. 203 and 204, is a shunt-wound machine designed to give sparkless commutation

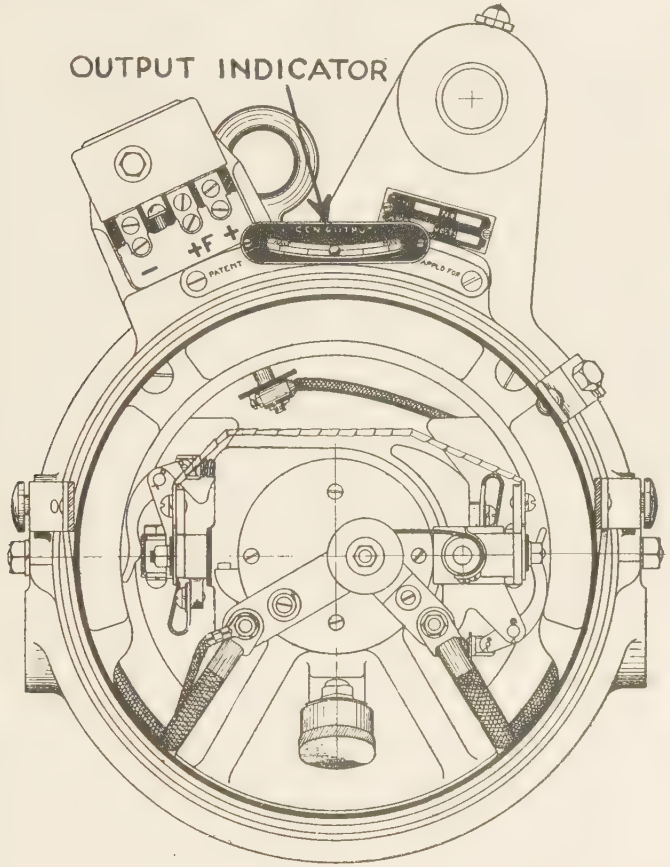


FIG. 204—End View of Generator Showing the Output Indicator.

through the range of loads and speeds met with in car lighting.

The main parts of the generator are as follows: magnet frame, pole-pieces, field coils, armature, bearings, pole-changer, brush holders and brushes.

Of special interest is the pole changer on which the flexible

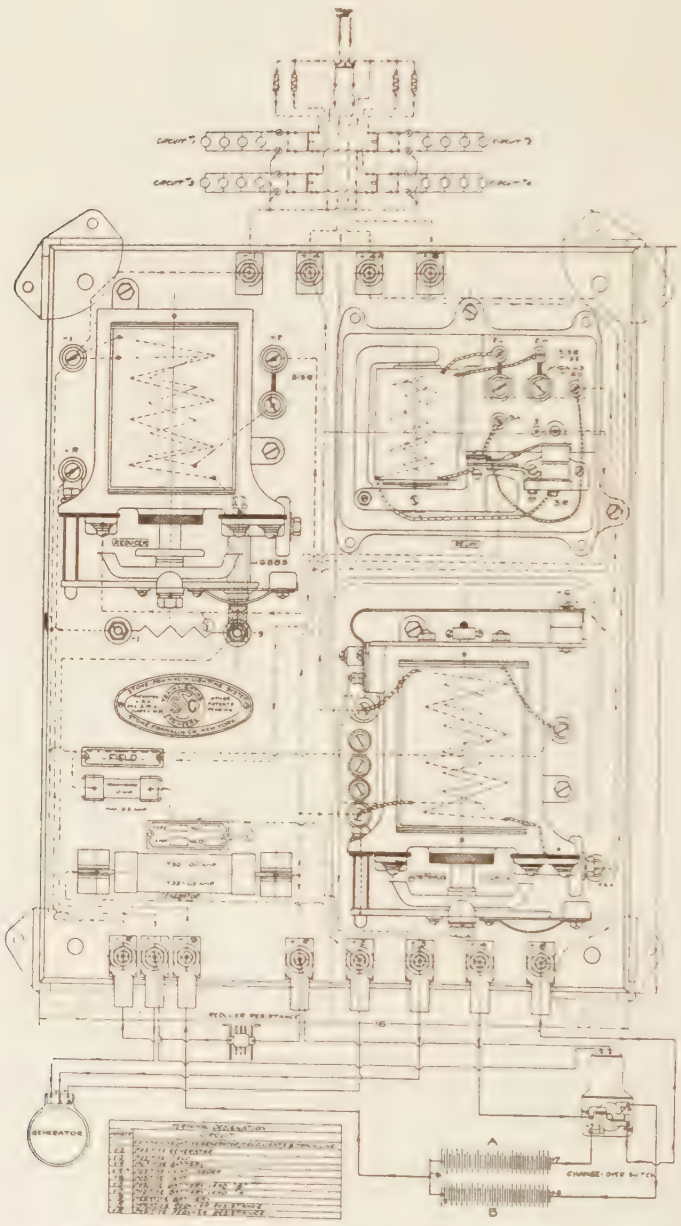


Fig. 205. Type A R D Automatic Panel for Double Battery Equipment.

leads are brought out beyond the brushes thus eliminating trouble due to leads catching brush holders. Destructive flexing of leads is also eliminated by an arrangement which permits the flexible leads to wrap around circular terminal posts.

The armature pulley for the Type 50 generator is 5½ in. in diameter.

The armature pulley for the Type 35 generator is 4½ in. in diameter.

For special low speed conditions, the T-35 generator is operated with a 3½ in. pulley.

The face of the armature pulleys used with the Stone-Franklin equipment is straight and must not be crowned.

The Stone-Franklin generators are suspended from the car body and made in two sizes as follows:

Rating	T-35 2-Pole 1.6 kw.	T-50 4-Pole 3 kw.
Amperes	40	75
Volts	40	40
Cut in speed r.p.m.	20	18
¾ Load speed r.p.m.	22	20
Full load speed r.p.m.	23	21
Weight of generator without pulley	310 lb.	480 lb.
Weight of armature	45 lb.	100 lb.

Automatic Panel.—The automatic panel, Fig. 205, is fitted with an automatic switch, reducer switch, and a relay switch.

In order to effect standardization of individual cells, the Stone-Franklin system has been designed to operate with either a single unit battery or a double unit battery, which gives the opportunity of standardizing on one type and size of cell. For instance, a 200 ampere-hour battery can be used for coaches, or any other class of car having a lamp load up to 20 to 25 amperes, while the same type and size of cell can be used for dining cars and other classes of cars having double that lamp load by using two sets of this type of battery in multiple. In such cases an automobile change-over switch is used to alternate the two battery units on the generator for effective charging. The Type AR panel is used for single battery operation, and the Type ARD panel is used for double battery operation.

Operating Features.—The generator is regulated by limiting the belt tension so that when the desired output has been reached,

the belt pulls the generator toward the axle pulley and the armature continues to rotate at practically constant speed, regardless of increase of train speed. A change in the external resistance of generator load will cause slight variations of the armature speed, as this mechanical control virtually results in constant torque, permitting the generator voltage to adjust itself automatically to the various conditions of the battery.

The belt tension, therefore, is very important, and adjustments should be made in accordance with a table of specified values, the tension being adjusted by the use of an output indicator which is fitted to the front head of the machine as shown in Fig. 204. This indicator operates on the principle of a spirit level, and translates the pull on the belt into terms of output. The tension is effected entirely by a portion of the generator weight, and no springs are used. By operating the hand wheel on tension rod of the suspension link, Fig. 206, the belt pull can be increased or decreased as desired. The setting of the belt tension should be in accordance with the following table.

Set Output Indicator at:

On T-50 with Lead Batteries
150 A. H. 2 degrees below full.
200 A. H. 1½ " " "
250 A. H. 1 " " "
300 A. H. ½ " " "
350 A. H. Full.

On T-50 with Edison Batteries
A-4-H 1 degree below full.
A-6-H Full.
A-8-H 1 degree above full.
A-10-H 2 degrees above full.

On the T-35 with Lead Batteries
150 A. H. ½ degree below full.
200 A. H. Full.
250 A. H. ½ degree above full.

On the T-35 with Edison Batteries
A-4-H Full.
A-6-H 1 degree above full.

If the T-35 generator operates with 3½ in. pulleys, belt tension must be increased so that indicator reads 1 degree above the values given. This applies to both lead and nickel-iron batteries.

Operating with Sulphated Battery. Due to the mechanical control of generator output, which results in constant torque, a sulphated battery is automatically taken care of as its high internal

resistance simply causes the generator voltage to increase, and thus a moderate charge passes through the battery. This is readily apparent from the fact that the generator voltage with this control is dependent, first, on the back e. m. f. of the battery, and, second, its internal resistance. As the watt output of the generator must remain practically constant, it again follows that the charge rate will be automatically reduced.

Operating with Discharged Battery.—For the foregoing reasons a discharged battery will receive at the beginning a heavier charge rate up to a certain gassing point, because of the low back e. m. f. of such battery. As the battery voltage rises, the rate of charge will gradually taper off. The belt tension settings given in the table are based upon maximum charge rates for the various

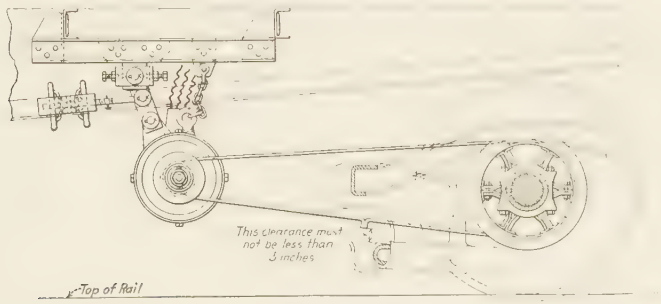


FIG. 206—Standard Application of the Stone-Franklin Equipment.

batteries which continue, however, only until gassing sets in, when the reducer switch, described later, functions and so cuts down the battery charge to normal. As the battery reaches full charge, with this normal rate, the relay comes into action, and through its functions, disconnects the generator entirely from the battery.

Battery Control.—The battery itself, that is, its own characteristics, are used to determine the state of charge; the battery governs the regulating apparatus and influences the generator quantitative output, in accordance with its state of charge. The apparatus, therefore, when once calibrated and adjusted, for a given type of battery, cannot get out of step with the charge of battery. To insure at all times a fully charged battery, the charge rate for a given battery at the initial stages of charge, is set for approximately twenty amperes above normal rate, and permitted

to flow through the battery provided it is in a receptive condition, until gassing sets in.

Reducer Switch. At the gassing point of battery the reducer switch, operating on the principle of watt control, functions in the following manner:

A shunt coil, which is virtually connected across the battery, when the main switch is closed, furnishes a definite number of ampere turns, which tend to operate the reducer switch. A series coil carries the battery charging current. The resultant ampere turns further assist the shunt coil. It is, therefore, the combined ampere turns of both battery voltage and battery current which cause the reducer switch to act and the combination is so proportioned that the gassing point in any type of battery can be effectively determined. When this point is reached, the reducer switch closes, and by completing a circuit through reducer resistance, a portion of the initial rate is absorbed and the battery now continues to be charged at normal rate until a definite voltage with this definite normal charge rate is reached.

Relay Switch.—Through the closing of the reducer switch, the lifting coil of the relay switch has been strengthened through the short-circuiting of a resistance tube in series with the lifting coil, and the relay switch is now calibrated to operate when the battery has reached its final voltage with the low charge rate. As soon as the relay armature lifts, a field resistance of high ohmic value is inserted in the generator field, and this action practically kills off the generator as it can only furnish approximately 5 volts regardless of train speed. Both main and reducer switches immediately drop out, and the generator, therefore, is entirely disconnected from the battery. The generator voltage, however, although only 5 volts, is sufficient to hold the relay armature until the train speed decreases to below 10 miles per hour, when the relay armature drops, and the equipment is restored to normal operation.

Lamp Voltage Regulation. - The lamp current is furnished by the generator, through suitable iron wire resistances enclosed in vitrous enamel to prevent deterioration. These resistances serve to reduce this supply current to the desired lamp voltage. To simplify the correct apportioning of these resistance units for a given circuit, the resistance unit has been given a number which corresponds to the wattage of the lighting load for which it will give correct regulation. For example, resistance unit No. 120 is

suitable for a lighting load of 120 watts. Therefore, for a lighting circuit of 240 watts, two units should be placed in parallel, etc. Where the wattage of a given lamp circuit is not an exact multiple of 120, the nearest multiple of resistance units should be selected. For instance, for a lamp circuit of 400 watts, the correct lamp resistances would be three No. 120 units.

The lamp voltage is further stabilized by a suitable and accurate floating voltage. In case of single battery operation, this stabilizing voltage is obtained from a definite number of cells of the battery on charge, and this connection is automatically disconnected from the lamp circuit, when the stabilizing voltage falls below the required lamp voltage. This operation is performed by

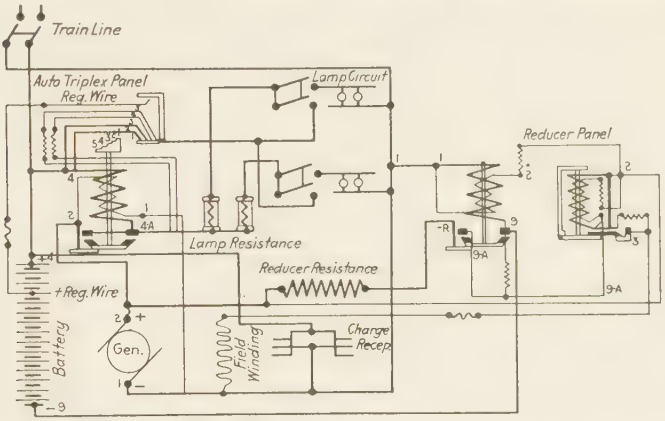


FIG. 207—Schematic Wiring Diagram for Single Battery Equipment.

the cut-in switch through the medium of regulating finger No. 5 on top of switch, as indicated in Fig. 207.

In double battery operation, the stabilizing voltage is derived from the battery unit which is not being charged, and in this case the regulating voltage is permanently connected to the lamp circuits. As the two units are constantly alternated by the automatic change-over switch on the generator, the regulating voltage is always obtained from a fully charged battery.

Adjusting.—With the generator inoperative the lamp voltage is not more than ½ volt less than battery voltage. A greater difference in these readings is an indication that the finger contacts on top of the main switch need cleaning.

The correct position for the suspension link is such that the

generator suspension pin is 3 in. closer to the driving truck than the top suspension pin, and the belt should be cut to proper length, so that this condition can be maintained.

The main switch is set to close at 30 volts, for both lead and Edison batteries, when lamps are switched off. With full lamp load on, the switch must close at 32 to 33 volts. The main switch will open or cut-out with a reverse current of 1 to 2 amperes with lamps on, and 4 to 5 amperes with lamps off.

The main switch is adjusted by the nut at the bottom to the left, and by the top core located under the elevator block.

For single battery operation the main switch plunger must raise the fingers successively, No. 1 finger lifting when the battery

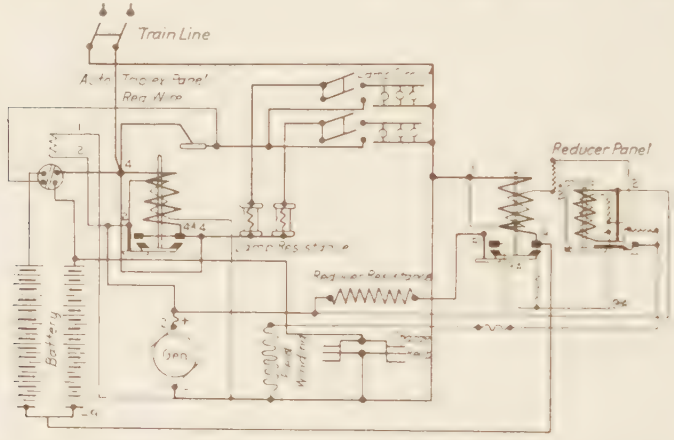


Fig. 208—Schematic Wiring Diagram for Double Battery Equipment.

receives a charge of 5 amperes. No. 2 finger with a battery charge of 10 amperes. No. 3 finger with a battery charge of 15 amperes. No. 4 finger with a battery charge of 20 amperes. No. 5 finger must make contact at the moment No. 4 finger breaks contact. The elevator block is furnished with screwed pins of bakelite, to facilitate the necessary adjustment.

For double battery operation all five fingers must be raised at once, and the bakelite pins must therefore be adjusted evenly. The five fingers then act as a single brush, and must be lifted when the battery charging current is 12 to 14 amperes.

Reducer Switch.—The reducer switch is calibrated on an open circuit without any current flowing through the series coil. Permit

the generator to build up its voltage on open circuit, by holding out the main switch. The reducer switch must close on open circuit for lead batteries at 45 to 45.5 volts, and for Edison batteries at 49 to 50 volts. Should adjustments be necessary, first set the nut at the bottom, so that the main brush tip is ½ in. from its contact, when the switch is open. Then adjust the top core until these results are obtained.

The switch must drop out again at a generator voltage of not more than 22 volts. If the switch drops out earlier, the carbon contacts will depreciate prematurely. To correct this, the top core must be screwed down, and the cut-in setting corrected by screwing the bottom nut further down. The set screws must be thoroughly tightened after adjustments have been made, the plunger should move freely, and it should be assured that the bottom nut is actually secured by its set screw.

To compensate for the various charge rates of different battery capacities, a shunt is placed across the terminals immediately below the reducer switch. This shunt is connected across the series coil of the switch, and in this manner the switch is calibrated for higher charge rates to suit the larger sizes of batteries.

Relay Switch.—This switch is calibrated with the reducer switch closed to operate from 42 to 42.5 volts with lead cells, and from 44 to 44.5 volts with Edison cells. With the reducer switch open, the relay operation will be retarded by some 5 volts, and in this manner the relay also serves as an open circuit protection. Set screws are provided for making adjustments.

Change-Over Switch.—This switch must lift before generator voltage is 28, and the plunger should drop out again at 1 to 1.5 volts.

Belting.—"Frisco" belting only should be used with the Stone-Franklin equipment. In case of an emergency, a rubber belt may be applied temporarily, but cutting the belt in two, and applying a two-inch belt.

Operation.—A schematic diagram of a single battery equipment is shown in Fig. 207; its operation is as follows:

Assume that the battery in this case is a 150 ampere-hour Edison—Type A-4-H—and the generator a Type 35.

When the car is standing and the generator inoperative, the current to the lamps is furnished by the storage battery. The

lamp voltage in this case will not be more than ½ volt less than the battery voltage.

When the car is in motion the generator voltage will build up due to the residual magnetism of the field pole pieces. At slow speeds there is generated in the armature a low voltage which forces a small amount of current through four parallel circuits, comprising the lifting coil of the automatic switch, the field circuit, the lifting coil of the relay switch, and the shunt coil of the reducer switch.

While the lifting coil circuit of the relay switch and the shunt

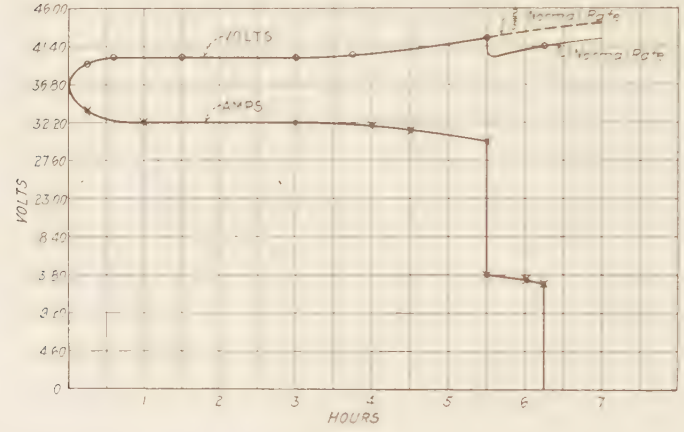


Fig. 209—Charging Current and Voltage Curve of Edison Battery.

coil circuit of the reducing switch are alive at this time, they remain inoperative until the battery reaches a certain state of charge.

As the speed of the armature increases and the current in the field circuit increases the field magnetic strength, the generator voltage also increases until it reaches 30 volts when lamps are switched off, or 32 to 33 volts when all lamps are switched on, at which time the automatic switch connects the generator to the car wiring.

The instant the automatic switch closes, all circuits become energized, the machine furnishing current for all lamps that may be turned on, but delivering only a small amount of current to the

battery. As the speed increases, the generator voltage rises and increases the battery charging current.

As the battery current increases, the finger contacts on top of the main switch are lifted successively.

The output indicator on the Type 35 generator, when operating with a A-4-H Edison battery, should be set at "full," and since the Type 35 generator has a capacity of 1.6 kw., "full" on the indicator represents 1,600 watts.

As the speed increases, the generator output increases until it reaches 1,600 watts. At this point a further increase in train

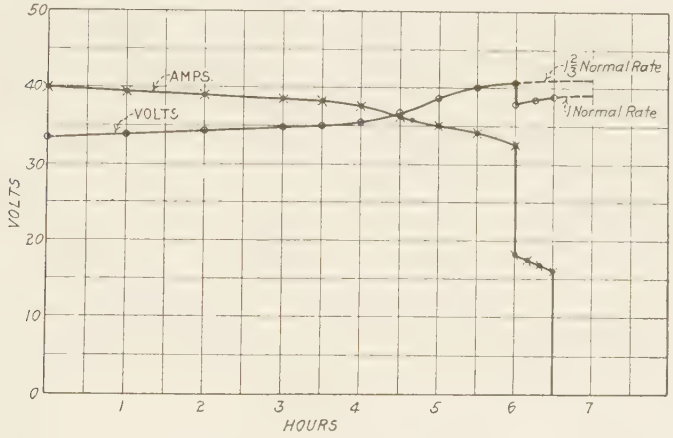


FIG. 210—Charging Current and Voltage Curve of Lead Battery.

speed will only cause the belt to slip over the generator pulley, the armature speed and generator watt output remaining constant.

From the instant the generator starts to build up, the shunt coil on the reducing switch is "alive" but the current through it is not sufficient to produce the magnetism necessary to lift its plunger. However, the generator voltage gradually increases as the batteries become more fully charged, and this rise in voltage effects a corresponding gradual increase in the current through the coil, until the gassing point of the battery is reached. At this point, the combined forces of the shunt coil and series coil of the reducing switch through which the battery charging current passes, are sufficient to operate the switch. The closing of the reducing switch reduces the battery charging current by connecting the

reducer resistance in multiple with the battery. It also shunts a resistance unit out of the relay lifting coil circuit, which allows the relay switch to operate at a lower voltage.

The battery charge will continue at the reduced rate until the voltage reaches approximately 44.5 volts, indicating a fully charged battery and closing the relay switch. As soon as the relay armature lifts, a field resistance of high ohmic values is inserted in the generator field, and this action practically kills off the generator as it can only furnish approximately 5 volts regardless of train speed. Both main and reducing switches immediately drop out, and the generator, therefore, is entirely disconnected from the battery. The generator voltage, however, although only 5 volts, is sufficient to hold the relay armature until the train speed decreases below 10 miles per hour, when the relay armature drops, and the equipment is restored to normal operation.

Figs. 209 and 210 are charging current and voltage curves of Edison and Lead Batteries, respectively.

CHAPTER XX

U. S. L. CAR LIGHTING EQUIPMENT

The fundamental principle of the U. S. L. car lighting system is *modified constant potential with ampere-hour control.* It differs from other systems in that the voltage coil is the dominating coil and its action is modified by the modifying coil as the charging progresses. At the point where the battery reaches a state of full charge, the ampere-hour meter comes into control and stops the charging process.

The U. S. L. system is made in several different types: Type "A" for use on cars which require only a small lamp load; Type "C" for use on other equipment requiring a more powerful lighting system; and special types to meet specifications of various railroads. All types, however, are based on the modified constant potential feature.

The U. S. L. type "A" equipment has been designed especially for such passenger cars as require only small lamp loads. This class of cars includes small coaches, baggage cars, combined baggage and smoking cars, and express cars, which as a rule do not require more than a 15-ampere lamp load at 32 volts, employing 16 cells of rather small capacity. A load of 15 amperes at 32 volts represents about 480 watts, and with the modern gas-filled lamp which develops about 1 c.p. per watt, it is possible to supply 480 c.p. actual illumination in cases of this kind. The storage batteries required do not ordinarily need to be of greater than 120 ampere-hours capacity, or even less, for such a battery represents an ability to carry a 15 ampere lamp load for eight full hours, which in this class of service is very exceptional. In most cases smaller batteries than 120 ampere hours may be employed; as small as 80 ampere hours for certain classes of service.

The battery consists of 16 cells for American practice where

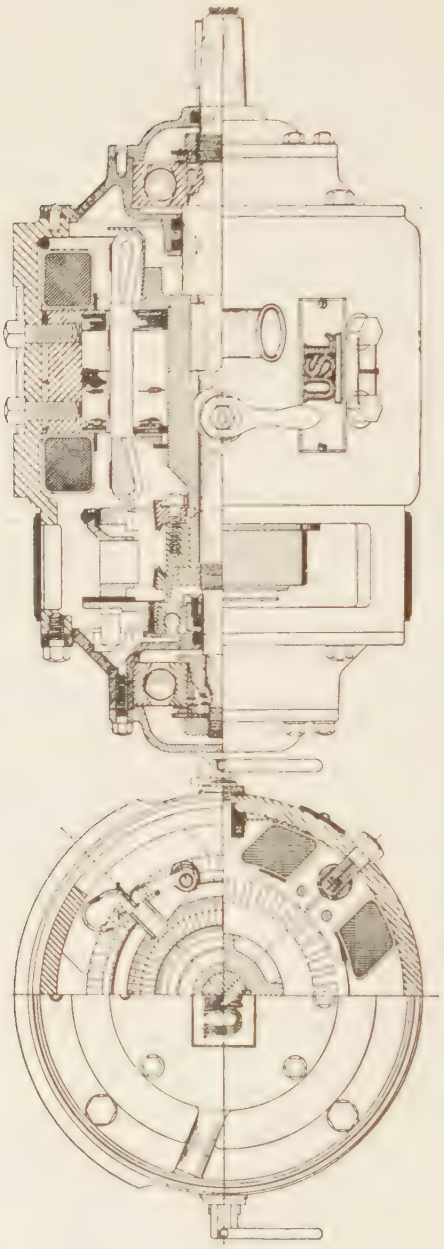


FIG. 211—Sectional Views of the U. S. L. Type "A" Generator.

the 30-volt system is standard and of 12 cells for English and foreign practice where the 24-volt system prevails.

The ampere hour meter may be applied to these small equipments if desired:

Generator.—The type "A" generator—Fig. 211—is a plain shunt-wound machine, designed to operate either in a 24-volt or a 30-volt system. It cuts in at 288 r.p.m. and carries full load at 320 r.p.m. in a 24-volt system. These speeds for a 30-volt system are respectively 360 r.p.m. and 400 r.p.m. It consists of a cylindrical steel casting universally machined so that it may be readily adapted either to a body suspension or to a truck suspension. The cylindrical barrel is provided with tapped holes so that adapters for either body mounting or truck mounting may be attached to the frame without any further machining. A majority of the holes are common to both methods of mounting; the holes that are left vacant in either particular arrangement are plugged by means of hollow set screws which leave the surface of the generator smooth and clean, and do not in any way impair the appearance of the apparatus.

Cast iron housings are bolted to each end of the cylindrical frame and contain and support the ball bearings on which the armature shaft rotates. These housings are provided with caps which cover and protect the ball bearings and form grease pockets having a capacity for enough grease to last twelve months without necessity for renewing the lubricating material. These housings are equipped with felt retaining gaskets, to prevent the escape of grease, and are perfectly machined, thus securing absolute alinement and concentricity of the armature in its bearings and in the pole pieces.

Two large handholes, one on each side of the generator at the commutator end, give access to the brushes and brush holders for inspection and renewal of brushes. The generator is equipped with the standard self-adjusting brushes mounted upon a brush rig supported on a ball bearing, which enables the brushes to be rocked back and forth with change of rotation of the armature, thus preserving the polarity of the terminals of the machine. The field poles are four in number and each is excited by its own coil. These field poles are all laminated and riveted together under very heavy pressure, so that the laminations form a practically solid

mass. The field poles are bolted into the frame and the pole tips form retainers which hold the field coils in place.

The armature is of the standard toothed-drum construction, the laminations being mounted upon a ventilated sleeve which also carries the commutator. The shaft is independently secured in the sleeve so that it may be removed without disturbing the rela-

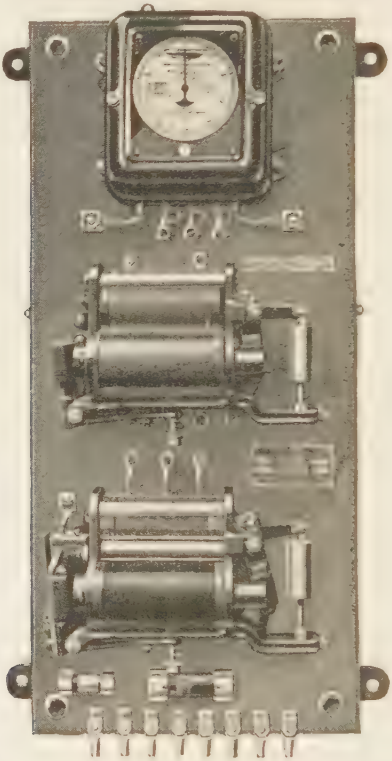


Fig. 212. Type "A" Form 201 Panel.

tion of the armature and the commutator. The commutator bars are made of drop-forged copper and a pure and soft grade of mica is employed for insulation. The retaining parts are all made of steel, so that there is no danger of breakage at any point. The armature shaft is made of high carbon steel.

Regulator Panel.— The regulating apparatus consists of two essential parts—the combined generator regulator and automatic

switch, and the lamp regulator, on a slate panel as in Fig. 212.

The combined automatic switch and generator regulator, or potential regulator, as it is called, consists of a brass frame and two electro-magnets with iron cores, a carbon pile, a contracting armature, and a regulating armature. The cores of the magnets are arranged horizontally, and each core is provided with a coil consisting of two windings, one a heavy or series winding, and the other a comparatively fine or potential winding. The potential windings are connected in series and across the terminals of the generator and they serve as the lifting coil for the automatic switch and as the voltage coil for the potential regulator. The two series coils are connected to a common insulated terminal on the automatic switch; one is placed in the battery circuit and the other in the lamp circuit. These coils act as the releasing coil of the automatic switch and also act as a modifying coil to modify the effect of potential regulation, which is secured by the voltage windings previously described.

The automatic switch consists of a bell-crank lever to which is secured a soft iron armature. Attached to the vertical arm of the lever is a contacting laminated copper brush provided with auxiliary carbon contacts for closing the main circuit between the generator and the storage battery and lamps. The horizontal portion of the bell-crank lever serves as a means of limiting the motion of the switch and adjusting the same. The armature of the automatic switch faces the left hand end of the magnet cores. At the right hand ends of the magnet cores is the regulating armature, which in turn is attached to a bell-crank lever controlling the pressure on the stack of carbon discs which form the variable resistance in the field circuit of the generator. The magnet cores, at the right hand end, are beveled out on the inside or opposing faces, and a wedge-shaped laminated armature is employed for actuating the carbon pile. As before stated, this wedge-shaped armature is mounted on the vertical member of the bell-crank lever, while the horizontal member is controlled by means of a vertical air dashpot. A normal tension or pressure is maintained on the carbon pile by means of a horizontal helical spring provided with nut-and-screw adjustment which is attached to vertical arm of the bell-crank lever.

The operation of the apparatus will be readily understood by reference to the schematic wiring diagram, Fig. 213. When the

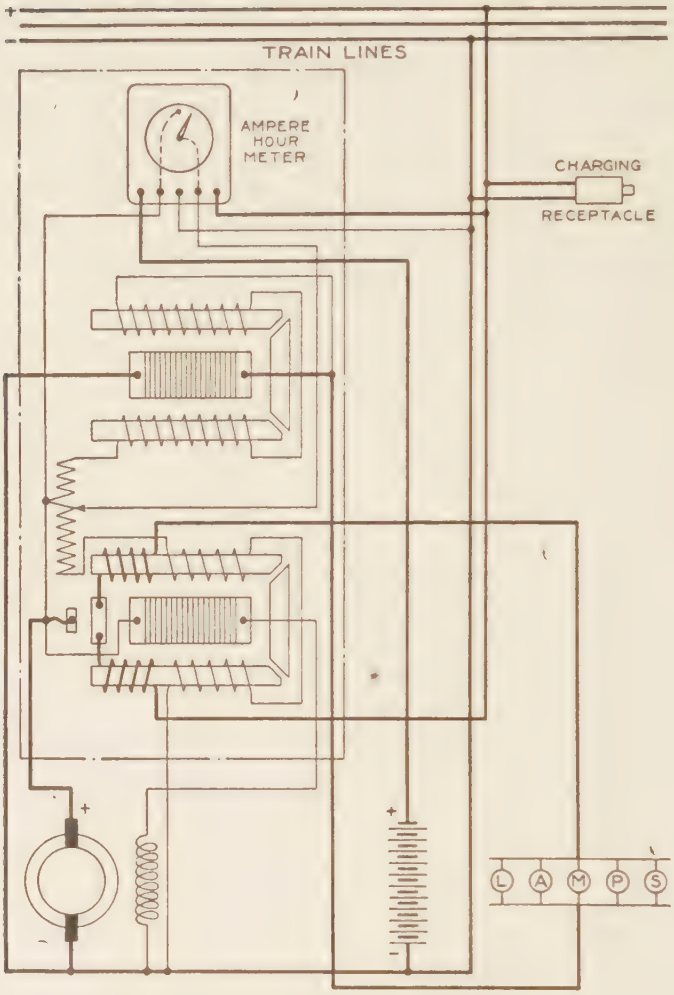


FIG. 213—Schematic Wiring Diagram of the Type "A" Equipment.

automatic switch is open the reluctance of the magnetic circuit through the cores, air gaps and armatures is so great that the voltage coils have no effect whatever upon the right hand armature which is used for controlling the pressure of the carbon pile. Consequently, during the time that the voltage is building up and the automatic switch is still open, while the voltage coils are excited on account of being connected directly across the generator terminals, they produce no effect on the armature which controls the carbon pile. After the automatic switch has closed, however, and its armature has come up into proximity with the left hand ends of the magnet cores, the reluctance of the magnetic circuit is so much decreased that a further increase in voltage impressed upon the voltage coils has the necessary effect upon the armature which controls the carbon pile, and from this point on regulation takes place, the tendency of the voltage coils being to maintain fairly constant voltage of the generator, which voltage is modified, however, by the action of the two series coils. The current flowing from the generator passes through the contacts of the automatic switch, thence into the two series coils on the regulator; and, as stated before, one of these series coils is in the lamp circuit and the other in the battery circuit. When the generator is furnishing the current for both these coils, they act cumulatively, and both tend to assist the voltage coils, thus producing a modified constant potential, as it is called. When the generator slows down below cutting-in speed the tendency of the battery is to discharge back through the automatic switch and generator. In doing so, the current through the series coil in the battery branch reverses and this, opposing the action of the voltage coils which tend to maintain the switch closed, causes the switch to open. The switch is adjustable so as to respond to whatever voltage may be desired, and this adjustment is effected by means of a spring on the horizontal arm of the bell-crank lever which constitutes the armature mechanism. Likewise, the air gaps of the armature may be somewhat regulated for effecting still closer adjustment.

With increase in voltage the pressure on the carbon pile is diminished, which increases the resistance in the shunt field circuit of the generator, thereby reducing the voltage and current of same or preventing any further material increase in either of these. By means of the spring attached to the lever of the armature which actuates the carbon pile, the output of the generator and likewise

its voltage may be varied through sufficient range to meet all the requirements of this equipment in actual service.

The lamp regulator consists of essentially the same parts as the combined generator or potential regulator and automatic switch, and employs the same type of frame magnet cores and substantially the same kind of armature and lever mechanisms, but has a carbon pile having discs larger in diameter and in thickness; the total length of the carbon stack is about the same. The carbon pile of the lamp regulator is connected directly in series with the lamps, and the voltage coils are connected directly across the lamps. There are no series windings on the lamp regulator. The right hand lever of the lamp regulator actuates the carbon pile in substantially the same manner as in the generator regulator. The dashpot and adjusting springs used are the same, both for steadying and adjusting this armature. On the left hand end of the lamp regulator a lever mechanism, similar to the lever and armature mechanism of the automatic switch, is employed, but the main contacts are omitted. This armature forms a movable back yoke or keeper for the magnetic circuit of the lamp regulator and acts somewhat in the nature of a vernier, or multiplier, or agitator.

The coils of the lamp regulator are not excited when the generator is at rest, and in this condition the armature or keeper on the left hand end of the lamp regulator falls back, due to the action of its retractile spring, and operates a back contact attached to the armature, by which the carbon pile is short-circuited and the intrinsic drop eliminated while the generator is at rest and the lamps are being fed directly from the storage battery. When the automatic switch closes, however, or due simply to the fact that the generator becomes operative, the coils of the lamp regulator are energized and the left hand armature is attracted toward the poles, thus closing to a certain extent the magnetic circuit and reducing the reluctance thereof. The right hand wedge-shaped armature which plays between poles fashioned similarly to those in the generator regulator is now free to act to vary the pressure upon the carbon pile, in order to maintain constant lamp voltage.

With each change in lamp load there is a corresponding change in lamp voltage, and this change in lamp voltage of course changes the strength of the current in the coils of the lamp regulator. This is followed by a change in flux, which causes the change in the position of the left hand armature, and there is thus added an

increased change in flux due to the fact that this armature moves toward or away from the poles of the magnet, as the case may be. This action stimulates or intensifies the normal action of the lamp regulator and serves to overcome the slight inaccuracy that is due to the mechanical friction in the working parts.

The voltage coils of both the lamp regulator and the combined automatic switch and generator regulator have connected with them, in series, high resistance units having zero temperature coefficient, thus reducing to a very small value the temperature error in these circuits. These resistances are made non-adjustable, and their values are determined at the factory. The only adjustment of the regulator is in the retractile springs and a ready means is provided for varying the strength of tension of these springs so as to produce the requisite voltage in the lamps or output of the generator.

It is not necessary to make any change in the resistance in the circuits of the voltage coils in either of these regulators, nor is it necessary to make any change in the settings of the armature with respect to their air gaps. These adjustments having once been made at the factory are permanent.

The Ampere-Hour Meter.—The ampere-hour meter is connected directly in circuit with the storage battery and measures the quantity of electricity charged into or discharged from the battery in ampere-hours. The meter closes a pair of contacts when the pointer comes to zero, indicating that the battery is fully charged, and these contacts short-circuit a portion of an adjustable resistance in series with the shunt or voltage coils of the generator regulator and thus strengthen or increase the action of those coils, causing the generator regulator to operate at a lower potential. This potential is known as the *floating voltage* and is 34.75 volts. If the potential regulator is set to maintain approximately 35 volts after the ampere-hour meter has closed its contacts then no current will flow into or out of the battery, provided the latter is fully charged, which the closing of the ampere-hour meter contacts indicates; under these conditions the battery is said to float on the line. The generator remains in a condition that enables it to carry the lamp load without disturbing the floating condition of the battery.

After a sufficient discharge has taken place at stations or stops, the contacts of the ampere-hour meter separate and restore the

generator to a charging condition; thus the batteries are replenished as soon as the generator becomes operative by reason of the car running again.

The curve sheet, Fig. 214, shows the relation between current and voltage as the regulator charges 16 cells of lead battery of 150 ampere-hour capacity. It will be noted that at the end of 8 hours the ampere-hour meter shows that 165 ampere-hours has been charged into the battery. At this time the contacts would

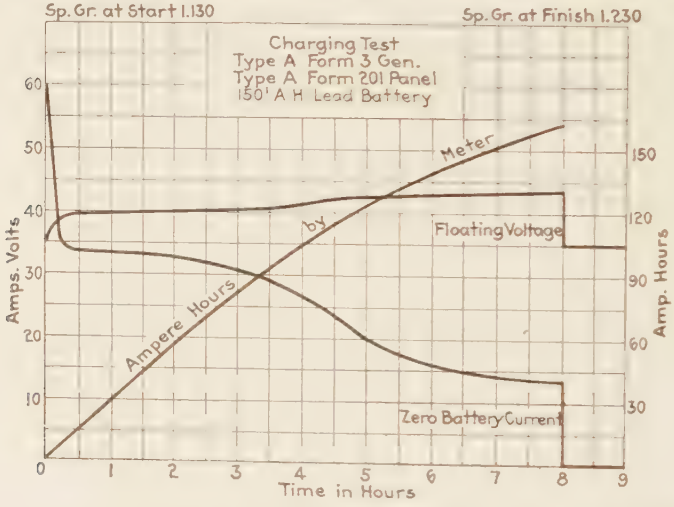


FIG. 214—Curves Showing the Relation Between Current and Voltage as the Regulator Charges 16 Cells of Lead Battery of 150-Ampere-hour Capacity.

close and reduce the voltage to floating value and the battery would "float."

In some cases where close lamp regulation is not necessary, the lamp regulator is omitted and certain fixed resistances are placed in series in each lamp circuit leading from the distributing panel. An auxiliary contact attached to the lever of the automatic switch is arranged to short-circuit these resistances when the generator is at rest and the lamps are being fed directly from the battery. When the generator is in operation and the automatic switch closed, these resistances are automatically thrown into the various lamp circuits and serve to protect these lamp circuits and lamps against excessive voltage. The use of these lamp resistances gives

good results for certain classes of work, such as in baggage and express cars, where there is no clerical work to be done by artificial light and necessity for close lamp regulation is not imperative. The lamp resistance method of protecting the lamps is in most cases sufficient and it is somewhat cheaper initially, as the cost of the lamp regulator is considerably greater than the cost of the lamp resistances.

Generator Suspension.—On account of its simplicity, lightness and lower first cost, the body suspension is in common use with this Type "A" equipment. The saddle casting which is bolted to the top of the generator frame in the body-hung generator—Fig. 215—is provided with two heavy supporting lugs, which are bored

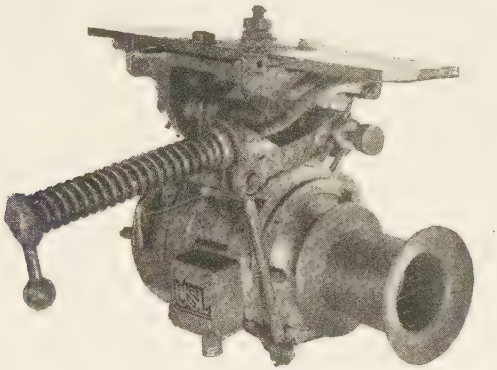


Fig. 215—U.S.L. Type "A" Generator with Body Suspension.

and fitted to the bushings to receive the supporting pin. This supporting pin likewise engages two depending lugs forming parts of the suspension bracket, which lugs are similarly machined and bushed and which straddle the lugs of the saddle. The suspension bracket consists of the two lugs mentioned and a horizontal portion cast integrally in steel. The top of the horizontal portion is designed in the form of a square, at the four corners of which are lugs cross tapped to receive set or adjusting screws. The suspension bracket is mounted against the suspension plate in such a manner that the four corner lugs of the former straddle the suspension plate.

The suspension plate is arranged parallel with the car or at right angles thereto. When parallel with the car it is generally attached

to supplementary angle irons or possibly to the transverse floor members; when arranged at right angles to the car, one end of the plate usually is attached to the center sill and the other end to the side sill of the car body. The set or adjusting screws which are threaded through the lugs on the corners of the suspension bracket impinge against the edges of the suspension plate and serve as adjusting screws to rotate the suspension bracket and generator about the central stud as a vertical axis, to secure exact parallelism of the car axle to the generator shaft. The saddle casting which is bolted to the top of the generator is always the same for any particular size or type of generator. The suspension bracket necessarily varies in design to meet special conditions under cars of different types and construction. The top of the suspension bracket, the location of the corner lugs, location and size of central stud and surrounding bolts always remain the same. The supporting pin which engages the lugs of the saddle casting and those of the suspension bracket is always of the same diameter but varies in length with the size and type of generator and sometimes on account of the spread of the lugs of the bracket.

Belt Tension Device.—The belt tension device of the body-hung suspension is of a very simple design and construction. It consists essentially of an I-shaped casting, the end of the horizontal portion being bored out and bushed to fit the projecting end of the main supporting pin. It is located on the pulley side of the suspension. Its vertical portion constitutes a support for the standard spherical spring seat used on truck suspensions. This casting or tension lever, as it is called, is turned away from the truck and its outboard end is secured by means of a short pin-connected rod to a stud bolted to the generator frame just below the center. A stud is fastened into the pulley side of the suspension bracket on a line above the suspension pin and on the truck side thereof. A tension rod having an eye in one end and threaded for a distance of a foot or more on the other end passes through the vertical portion of the tension lever, its eye engaging the stud referred to. The spherical spring seat bushing is slipped over the free end of the tension rod and into place against the tension lever. The tension spring is put under tension by means of a standard gravity tension nut on the tension rod.

Constant Belt Tension is maintained by a very simple mechanism which preserves a substantially constant belt tension over a

wide angle of swing of the generator, from a vertical position to one in which the center of the shaft of the generator has been drawn by the belt some six inches toward the truck.

When the generator hangs vertically the only tension exerted upon the belt is that due to the action of the tension spring which tends to rotate the generator about the supporting pivot in a direction away from the truck. The moment-arm of the tension spring or its leverage is the distance from the supporting pivot of the generator to the center line of the tension rod taken at right angles to the latter.

If the generator is swung toward the truck out of the perpendicular, another force is added to the tension of the belt, namely, a certain portion of the weight of the generator, so that in this new position the belt tension is composed of or due to two forces: first, the tension of the spring; second, the weight factor of the generator. The further the generator is swung from the perpendicular the greater the weight factor becomes, but at the same time the moment-arm or leverage of the tension spring becomes rapidly shortened and therefore, as the weight effect increases, the spring effect decreases. By properly choosing the strength of the spring, its initial tension, and correctly proportioning the parts of the tension mechanism, the net tension in the belt may be kept practically constant over the working range or swing of the generator.

When the center line of the tension rod passes exactly over the center of the pivot support, which is provided for by the hump or offset in said rod, the effect of the spring becomes zero and the weight factor is the only force producing tension in the belt.

If the center line of the tension rod should pass below the center of the pivot support of the generator the effect of the spring would reverse in its action and oppose the weight effect of the generator. Such a condition never obtains, however, but it is possible according to theory.

In practice it is customary to swing the generator shaft about 2½ in. out of plumb toward the axle and to cut and fasten the belt to hold the generator in this position. The tension is then set up to the required degree by compressing the tension spring until it is a specified length. The tension in the belt will then remain practically constant as the distance between the car axle and the generator varies, due to the relative motion between the

car body and truck, and the generator swings about its supporting pivot in accommodation to this motion.

The U. S. L. Type C, car lighting equipment consists of a generator, driven by a belt from the car axle, a generator regulator panel, a lamp regulator panel mounted in a cabinet inside or under the car body, and a storage battery which is suspended in a box under the car body.

Generator.—The generator Fig. 216 used with Type "C" equipment is a four-pole, shunt-wound machine designed to give

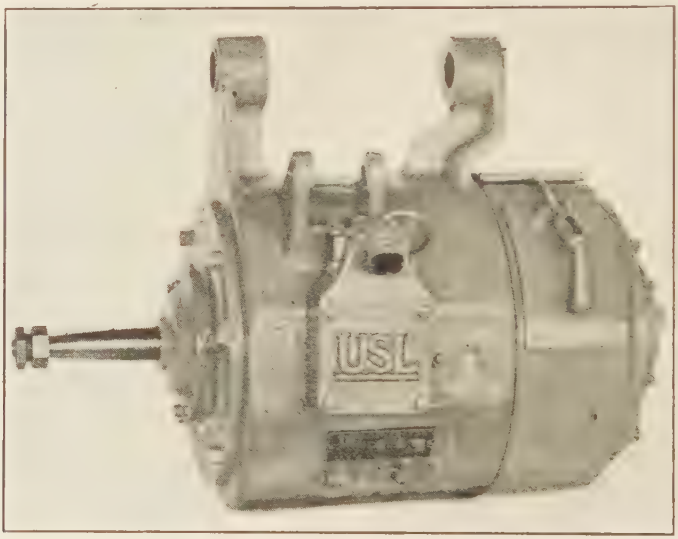


Fig. 216—U. S. L. Type CBH, Form 17, Generator.

sparkless commutation with the varying speeds and varying loads met with in car lighting.

The generator consists of the following main parts: magnet frame, pole pieces, field coils and retainers, armature, bearings, combined pole changer and brush rigging and brushes.

The magnet frame is a one piece steel casting. The housing heads which carry the bearings are bolted to the magnet frame at each end. Handholes, with water and dust proof covers, are provided at the commutator end for inspection purposes.

The pole-pieces are of the laminated type and bolted to the magnet frame. The armature is form wound with conductors

having heat proof insulation. The coils are held in the core slots by band wires. The armature core is built up of transformer iron laminations, and air spaces are provided in the core to secure cool running. The commutator bars are of hard drawn copper with liberal wearing depth and ample area to carry the maximum output of the generator. The armature shaft is made from high-grade steel accurately ground to size. The pulley, in addition to having a tapered seat, is keyed to the shaft and locked with a Columbia lock nut. The armature shaft rests in annular ball bearings, of a type developed especially for this service. Space is provided around the bearings for grease for lubrication; grease grooves and felt washers prevent the entrance of dirt into the bearings and the leakage of grease into the portions of the dynamo where it should not go.

The pole changer is of the rotating type, the direction of the current from the dynamo being kept constant by rotating the brushes through an angle of 90 degrees whenever the direction of rotation of the armature is changed.

The four brush boxes are mounted on a brush rocker and are insulated from it by fibre insulators. This brush rocker is mounted on a ball bearing and is free to rotate between two stops 90 degrees apart. While running in one direction, the friction caused by the pressure of the brushes against the commutator holds the brush rocker against one of the stops, with the brushes in the proper position for the sparkless commutation for this direction of rotation. Reversing the direction of rotation causes the brush rocker to be turned over against the other stop, changing the position of the brushes 90 degrees. The generator then gives the same polarity, although the direction of rotation has been reversed.

The brushes are made of carbon and provided with flexible copper pigtails to give positive contact with the brush box. Each brush is provided with a separate pressure spring of such design that the pressure on the brush is constant until the brush reaches its limit of wear.

Generator Regulator. The generator regulator panel, Type C Panel, with ampere-hour meter—Fig. 217—consists of a slate panel on which are mounted the automatic switch, field rheostat or carbon pile, regulator adjustments, solenoid with its respective

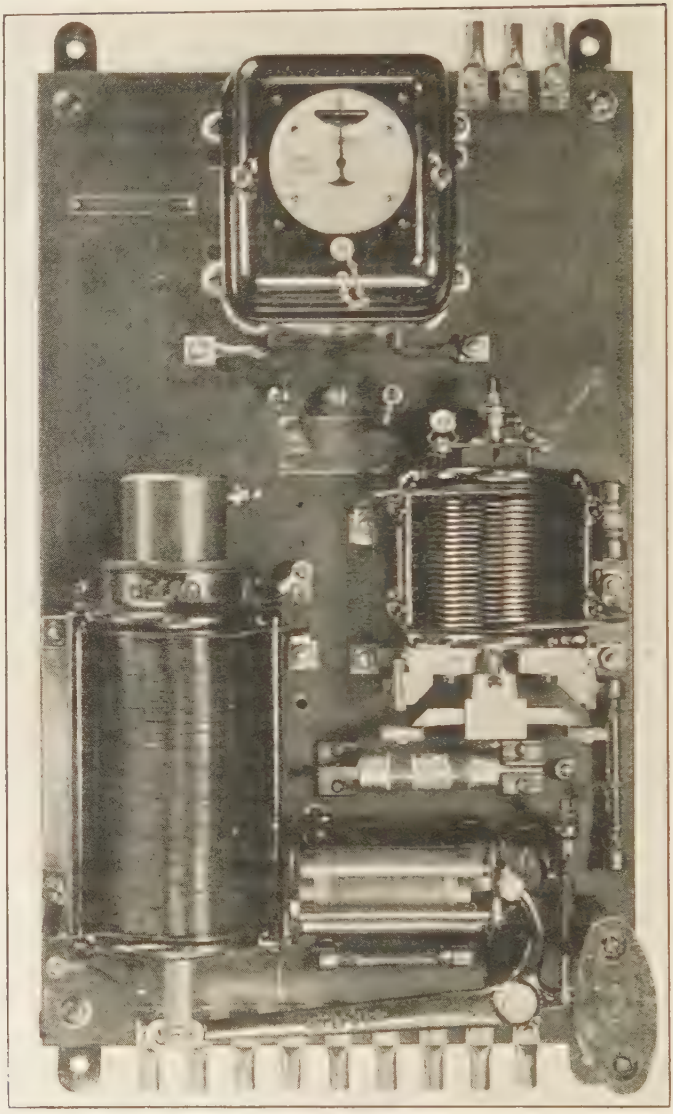


Fig. 217—U. S. L. Type C, Form 303, Generator Regulator Panel with Ampere-Hour Control.

plunger and connecting lever arms, main and field fuses, and Sangamo ampere-hour meter.

The automatic switch is of the solenoid type consisting of a fine wire shunt or lifting coil, a series or releasing coil of heavy copper strip, plunger, main and auxiliary contacts—see schematic diagram Fig. 218. The main contacts of the switch are at the bottom, but at the top an auxiliary contact switch is operated by the same plunger which opens when the main contact closes. This auxiliary switch puts resistance in series with the lifting coil, which reduces the current in the lifting coil considerably. By having this resistance cut into the lifting coil circuit

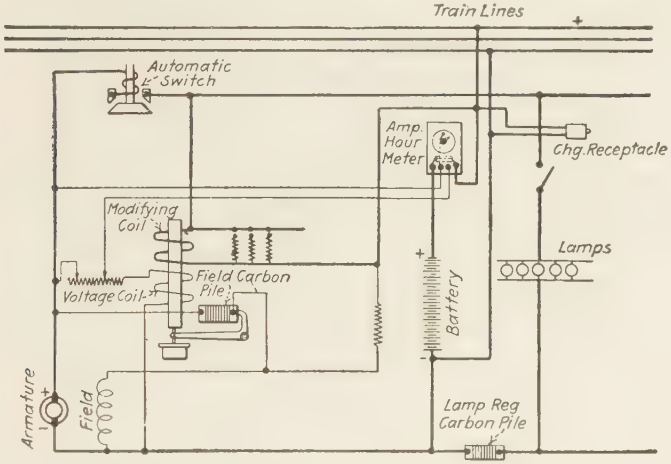


Fig. 218—Diagram Type C Panel Modified Constant Potential Regulation.

with main switch closed, these advantages are obtained: The lifting coil is connected directly across the armature circuit and exerts a maximum pull at 32.5 volts before the switch is closed. The resistance in series with the lifting coil keeps it from over heating at high generator voltages. Also the increased resistance in the lifting coil circuit insures a quick release of the automatic switch, because the coil is so weak that only a little reverse current in the series coil is necessary to open the switch.

The field rheostat or carbon pile is connected in series with the field circuit. The resistance of the carbon pile is automatically adjusted by movement of the plunger of the regulating solenoid.

The regulating solenoid consists of two coils, a modifying or

series winding which is connected in series with the ampere-hour meter and the battery, and a shunt winding which is connected across the generator terminals and in series with a variable resistance.

The modifying or series coil will regulate the current delivered by the generator to the battery to a certain value. To increase the battery charging rate, one or more shunt strips of resistance ribbon are connected across the modifying coil on binding posts provided for this purpose.

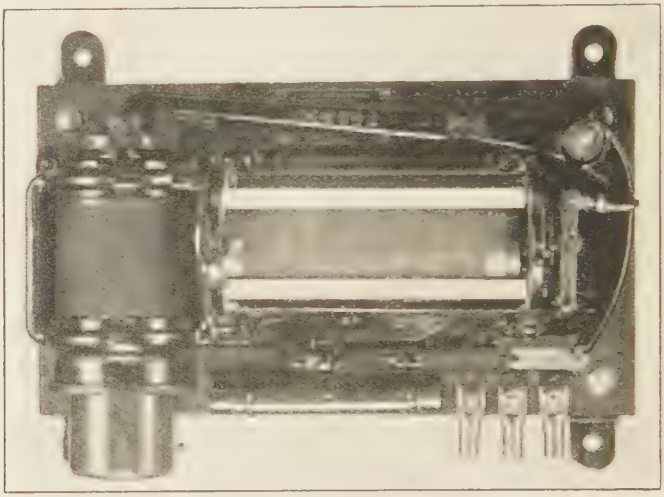


Fig. 219—U. S. L. Type B Lamp Regulator for Normal Loads.

The shunt winding, when acting alone, actually maintains a constant generator voltage. If this voltage rises, the current through the coil increases, the upward pull of the plunger which is connected to the field carbon pile through the lever increases, diminishing the pressure on the field carbon pile, so that the generator field is weakened, the result being to lower the generator voltage to its former value. A decrease in the generator voltage produces a similar but opposite effect.

An adjustable resistance is connected in series with the shunt coil as a means of adjusting the operating voltage of the coil.

The ampere-hour meter is equipped with a zero contact. When the ampere-hour meter hand returns to zero, indicating a full

charge, it closes this contact which short circuits a resistance in series with the regulator shunt coil. This action lowers the generator voltage and the battery floats on the line.

Lamp Regulator.—The Type B lamp regulator—Fig. 219—consists of a carbon pile and a solenoid having a vertically mounted and operating plunger which, through a compound lever mechanism, varies the pressure on the column or stack of carbon discs. The normal pressure on the carbon discs is supplied by means of a spring attached to the lower end of the vertical member of the bell crank lever, the other end being attached to a stud carried in a bracket which forms an integral part of the surbase. A castellated nut on this stud permits adjustment of the spring tension.

The main lever, which is of bell-crank form, having horizontal and vertical portions, is mounted by means of a ball bearing on a stud secured to a heavy boss which forms a part of the surbase. A small vertical lever, provided with two rollers, is also mounted on a stud and boss, forming a part of the surbase. The lower roller bears upon the stud of the thrust plate which imparts pressure to the carbon pile. An adjusting screw, which passes through the vertical portion of the bell-crank lever, imparts motion to the upper roller in the end of the vertical lever, to the latter. The carbon pile is supported by means of two lower support rods and held in place by means of two upper similar rods, these rods being insulated by means of lavite tubes. These rods are easily removable by means of the thimbles which are screwed into the right hand member of a carbon pile supporting bracket. The carbon pile is confined between two thrust plates, the left hand thrust plate being stationary and insulated from the frame of the regulator, the right hand thrust plate being movable and likewise insulated, and being provided with a horizontal stud which passes through a graphite bushing supported by the right hand member of the carbon pile bracket.

The right hand thrust plate is provided with a compression spring which moves the thrust plate in such a direction as to relieve pressure on the carbon pile, the function of this spring being to cause the thrust plate to follow the releasing motions or movements of the lever mechanism. This construction of movable thrust plates insures a frictionless movement of the same and one

that maintains the exact parallelism of the thrust plate at all times.

The entire carbon pile bracket may be quickly removed from its position and by disconnecting the flexible leads or pigtails of the thrust plates, the whole carbon pile system may be removed for inspection or renewals without disturbing the lamp regulator.

The solenoid frame may also be removed from the base without taking down or disturbing the lamp regulator, which constitutes a very important feature of construction in this class of apparatus. The solenoid frame is provided with a standard bakelite dashpot for damping out slight fluctuations.

The lamp regulator is arranged with three main terminals on the lower margin of the slate to the right of the center, which register with three terminals, which will be found on the upper margin of all standard panels, to the right of the center, so that the lamp regulator may be mounted above the panel and connected to the system by simply joining the three terminals on a lamp regulator with the corresponding three terminals on the panel.

The only two adjustments of the Type B lamp regulator are made by means of screws, all resistance units being fixed in value. These adjustments are in the screw in the vertical portion of the bell-crank lever and the nut on the tension spring stud. By means of these two adjustments the lamp regulator may be fully adjusted. The Type B lamp regulator is designed for normal lamp loads. For large loads the Type C lamp regulator is used.

The operation of the U. S. L. equipment is as follows: When the car is standing and the generator inoperative, the current to the lamps is furnished by the storage battery. When the car is in motion the generator voltage will build up, due to the magnetism of the field pole pieces. At slow speed there is generated in the armature a low voltage which forces a small amount of current through three parallel circuits comprising the automatic switch lifting coil, the field circuit, and the voltage coil of the generator regulator solenoid.

As the speed of the armature increases and the current in the field circuit increases the field magnetic strength, the generator voltage also increases until it reaches 32.5 volts, at which time the automatic switch should close and connect the generator to the car wiring.

The instant the automatic switch closes, all circuits become

energized, the machine furnishing current for any lamps that may be turned on but delivering only a small amount of current to the battery. As the speed increases, the generator voltage rises and increases the battery charging current until it reaches its maximum value. Assume the battery to be in a discharged condition, and the regulator connected for the battery charge regulation; the maximum battery charging current referred to is held nearly constant and passes through the series or modifying coil of the generator regulator solenoid. At this point it must be remembered that both "series" and "shunt" coils of the generator regulator solenoid are alive and operating or exerting their effect on the solenoid plunger.

As stated, the series or modifying coil maintains the battery charging current nearly constant with a battery in a discharged

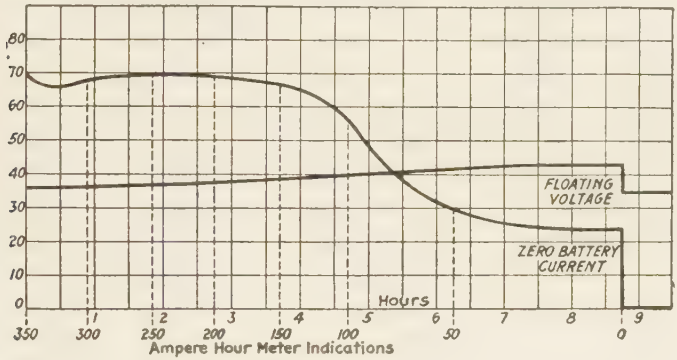


FIG. 220—U. S. L. Ampere-Hour Controlled Battery Charging Curve.

condition. As the battery charges its voltage rises; then the generator voltage is raised by the action of the modifying coil until the charging current again reaches its maximum value. This continues until the battery voltage rises to the point where the potential coil overcomes the effect of the modifying coil. Thereafter the potential coil maintains practically constant generator voltage and the charging current gradually tapers.

This principle of regulation is strictly a modified constant potential and is governed by the E. M. F. of the battery. At the beginning of charge, the charging current is fairly heavy, but as the charge progresses, it tapers to about one-half its initial value in eight hours. This rate continues until the ampere-hour meter

hand returns to zero, indicating a full charge, at which time the contact closes and the generator voltage is reduced to a floating value, the charging current dropping to zero. The floating voltage for a 30-volt system is 35 volts, with lead battery. During the battery floating period the generator regulation is straight constant potential. There is one other condition at which the regulation becomes constant potential and that is when there is an open battery circuit before the ampere-hour meter has acted. Under this condition the voltage coil will regulate at 45 volts and as there is no current flowing in the battery circuit the modifying coil has no effect.

This is best illustrated by means of a curve as in Fig. 220. The current started at 70 amperes and gradually tapered until during the fourth and fifth hours the current was rapidly falling, assuming finally a value of about 24.5 amperes at the end of the ninth hour, which is then reduced to zero by operation of the ampere-hour meter.

Referring again to the charging curve, Fig. 220, it is assumed that at the beginning of charge the ampere-hour meter hand stood at 350 ampere hours, indicating that the battery had previously had 350 ampere hours taken out of it. It will be seen that the area under the charging current curve is 437.5 ampere hours which was put into the battery in 8.75 hours, or at an average rate of 50 amperes, being 70 at the start and 24.5 at the finish. As it would require 437.5 ampere hours put into the battery in order to get 350 out on the next discharge, the ampere-hour meter is so arranged that it will require the passage of 437.5 ampere hours to drive the hand back from 350 to 0. At the end of 8.75 hours the hand of the ampere-hour meter has been driven back to zero and the contacts brought together. These contacts short circuit a portion of the resistance in series with the voltage coil of the generator regulator and thereby strengthen the voltage coil, which has the effect of reducing the generator voltage. At the termination of the charge of 437.5 ampere hours at the end of the eighth hour of continuous charging, the ampere-hour meter comes into control and stops the charging process by reducing the generator voltage to floating value—35 volts, 30-volt system. The voltage drops suddenly from 43 to 35 volts and the finishing and reduced charging current from 24.5 amperes to zero. This

condition exists until after a 50-ampere-hour discharge from the battery, when the meter contacts will open.

The lamp current does not flow through the modifying coil and consequently has no effect on the regulation or rate of battery charging; the lamp load is picked up by the generator alone, when it is running.

Adjusting Automatic Switch.—The laminated copper contact of the automatic switch should be adjusted in the stirrup so that when the plunger is lifted this laminated copper contact makes perfect contact with the stationary contacts on the switch frame. When the plunger is lifted and pushed home the copper leaf brush should bend but slightly. Allow the plunger to drop and then again raise it so that the brush comes within $\frac{1}{10}$ in. of making contact. Adjust the side carbons by means of the cap screws so that they just rest upon the carbons attached to the phosphor bronze leaf spring, when the plunger is in this position. The short leaf-spring of the auxiliary contact at the top of the switch should exactly reach its lower position. The point of the stud in the auxiliary lever should enter the hole in the copper strip; this stud should be adjusted so that the auxiliary contact is broken just at the moment the carbons come in contact. The castellated nut on the tail rod of the top of the switch should be adjusted so that with 32.5 volts impressed upon the lifting coil of the switch, the latter will close. This may be done by making the distance from the top of the stirrup to the key which prevents the plunger from turning and holds the tube in place, $\frac{5}{8}$ in. to $\frac{3}{4}$ in.

Adjusting Generator Regulator When Not in Operation.—Examine the field carbon pile and see that the proper number and size of carbon discs are in place. Examine support rods and tubes carefully to see that none are bent or broken. The plunger and lever mechanism should work freely without binding or sound. When the carbons are compressed the whole pressure should come upon the carbons and no parts of the moving mechanism arrested by coming into contact with stationary members. This is best done by opening the dash-pot vent. The lever mechanism when moved up and down by hand should bounce on the carbon pile when released quickly.

Testing Type "B" Lamp Regulator.—Examine the carbon pile and see that it contains 32 discs $2\frac{3}{8}$ in. in diameter and $\frac{3}{16}$ in.

thick. The carbon pile should measure 6 in. in length when compressed. Open dash-pot vent and work lever up and down by hand to see that mechanism is free from sticking and sound. The conical compression spring under armature disc requires 8 to 12 pounds pressure; it should be rejected if these limits are departed from. The dash pot should be removed and the piston unscrewed from the plunger tail rod. Set dash pot on level surface; insert piston until top of piston and pot are even; close vent tightly. Then release piston and time the descent, which should require from 45 to 60 seconds. Replace piston and dash pot, replace carbons if they have been removed and adjust screw in vertical member of bell-crank lever until its long arm just begins to move downward—about $\frac{1}{64}$ in. at top of solenoid. This insures pressure being on discs at all times. Turn on smallest lamp load likely to occur and adjust tension spring nut until the voltage on lamps is 31.

It is well to allow the lamp regulator to run with full load for half an hour before final adjustment is made, as the adjustment should be made with regulator fairly hot. The short auxiliary lever should stand nearly vertical when adjustments are completed. This adjustment should be checked when equipment is in operation with different lamp loads.

Testing and Adjusting Type "C" Regulator.—With the generator operating and lamps turned off check the automatic switch closing voltage.

If correctly adjusted it will close at 32.5 volts. If it closes before 32.5 volts are reached, unscrew nut on tail rod and increase air gap in switch, or if it does not close until after 32.5 volts are reached, screw up on this nut and lock with cotter pin after correct adjustment has been secured. By carefully raising and lowering the lever of the generator regulator, the generator voltage may be varied at will and the adjustment of the automatic switch tested completely. The automatic switch should open when the voltage has dropped to about 27 volts and the ammeter should indicate about 5 amperes reverse or releasing current.

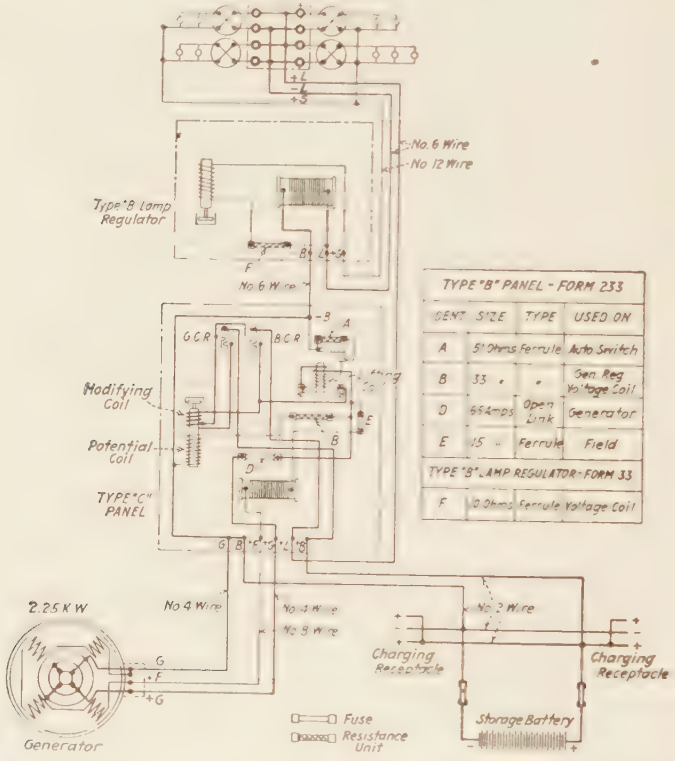
Turn the pointer of the ampere hour meter beyond 50 to be sure contacts are open. Then raise the lever of the generator until the ampere-hour meter disc comes to a dead stop, and then open the battery circuit. If there is no battery switch, disconnect the positive battery wire at bottom of the panel. Slowly lower the

lever, observing voltage. Remove hand from lever and move right hand slider on resistance unit at top of panel to extreme right hand position. The voltage should be about 50. Then move the slider to the left until voltage is reduced to 45; this is the open battery voltage adjustment and is to remain. Turn the pointer of the ampere-hour meter to zero to close contacts and observe reduction in voltage. Adjust the left hand slide until voltage is exactly 35; this is the floating voltage corresponding to zero current through the battery as the battery circuit is open. Turn the pointer again beyond fifty and observe that voltage goes back to 45. Then close the battery circuit and observe that the voltage drops to an intermediate value between 35 and 45, and that the battery takes a charging current. Make no further voltage adjustment.

Set the pointer of the ampere-hour meter so that the meter is in step with the battery. In Fig. 220, showing the charging curve of the panel and battery, on the bottom line marked "meter scale," the setting of the ampere meter is found. From this point run vertically up to the charging curve and read the number of amperes on the left-hand vertical scale; compare the ammeter with this number. If the ammeter reads less add shunt strips to the modifying coil or panel until the ammeter reads correctly; if the ammeter reads more remove shunt strips until the correct current flows. The panel is then properly adjusted and the battery and ampere-hour meter are in step. When the battery becomes fully charged, the ampere-hour meter hand will come to zero, the contacts close, the voltage will reduce to 35 and the battery will stop charging and float on the line. The generator will carry the lamp load independently of these conditions.

The U. S. L. Equipment—P. R. R. Specifications—consists of a Type CBH Form-17 generator, Type CP Form-233 generator regulator, Type B Form-33 lamp regulator, and Type A-4-H Edison battery. The generator is a four-pole, shunt wound machine, rated at 2.25 k.w. 45 volts and representing a generator capacity of 50 amperes. This generator has a cutting-in speed of 250 r.p.m. and a full load speed of 333 r.p.m. On a car equipped with 36 in. wheels and an 18-to-8 reduction, that is, 18 in. axle pulley and 8 in. armature, this generator will cut in at a train speed of 12 miles per hour and carry full load at a train speed of 15.9 miles per hour. It will also operate safely

at a train speed of 75 miles per hour with wheels worn to the limit. Therefore, this equipment is suitable for either branch line service where the train speeds are low, or main line service where higher train speeds are attained.



TYPE "B" PANEL - FORM 233			
IDENT.	SIZE	TYPE	USED ON
A	5 Ohms	Ferrule	Auto Switch
B	33 "	"	Gen. Reg. Voltage Coil
D	65 Amps	Open Link	Generator
E	15 "	Ferrule	Field
TYPE "B" LAMP REGULATOR - FORM 33			
F	10 Ohms	Ferrule	Voltage Coil

FIG. 221—Wiring Diagram of U. S. L. Equipment. (P.R.R. Specifications.)

Generator Regulator. The generator regulator consists of a slate panel on which are mounted the automatic switch, field rheostat or carbon pile, regulator solenoid, with its plunger and lever arms, a main and field fuse, and adjustable links.

The automatic switch is the same as previously described for Type C equipment. The field rheostat is connected in series with the field and contains approximately 93 discs, which are $\frac{1}{32}$ in. thick and $1\frac{1}{2}$ in. diameter. The resistance of this pile is automatically adjusted by movement of the plungers of the regulating

coils. The solenoid consists of two coils, a potential coil and a series or modifying coil.

The adjustable links are used for connecting the regulator for either generator current regulation, or battery current regulation. The resistance unit in series with the potential coil has a resistance of 33 ohms.

The pull of the regulator solenoid plunger is opposed by a spiral spring and a movable weight attached to the lever arm.

The Type "B" U. S. L. lamp regulator used with this equipment has been previously described in this article.

Storage Battery.—The storage battery used with the U. S. L. equipment (P. R. R. specifications) consists of 25 Type A-4-H Edison cells. This battery is assembled in five trays, five cells per tray, and has a capacity of 150 ampere hours.

The lead storage battery may also be used with this equipment.

Operation.—A wiring diagram of the U. S. L. equipment conforming to P. R. R. specifications is shown in Fig. 221; the operation is as follows:

When the car is standing and the generator inoperative, the current to the lamps is furnished by the storage battery. When the car is in motion, the generator voltage will build up due to the residual magnetism of the field pole pieces. At slow speeds there is generated in the armature a low voltage which forces a small amount of current through three parallel circuits—the lifting coil of the automatic switch, the field circuit and the potential coil.

As the field of the generator is increased, and the current in the field circuit increases the field magnetism strength, the generator voltage also increases until it reaches 32.5 volts, at which time the automatic switch should close and connect the generator to the car wiring.

The instant the automatic switch closes, all circuits become energized, the machine then furnishing the current for any lamps that may be turned on, but delivering only a small amount of current to the battery. As the speed increases, the generator voltage rises and the generator current increases until the regulating solenoid goes into operation. The generator regulator is of the modified potential type which has been described. This equipment, however, does not have the ampere-hour control, and the charging current, when the battery is fully charged, tapers

to approximately 10 amperes. In addition to this, the regulator is designed so that it will either regulate the battery charging current or the total generator current.

With the first method, known as "battery current regulation," the battery current flows through the entire modifying coil, and all lamp current will simply be added to the generator load, without affecting the amount of charging current. With the

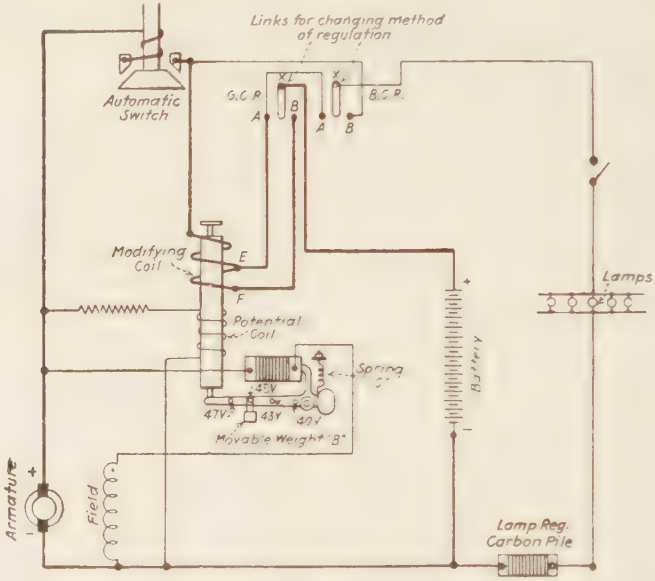


FIG. 222—Type "C" Panel Schematic Wiring Diagram. (P.R.R. Specifications.)

second method, "generator current regulation," the total useful current, that is, the battery charging current plus lamp load, will flow through a section of the modifying coil. The entire modifying coil is not used for this method of regulation.

The change from one method of operation to the other is made by throwing two links. The schematic diagram, Fig. 222, shows how this change is made. When the links are to the right and connected to terminals B, the modifying coil controls up to a certain point; the battery charging current and the lamp load is picked up by the generator because the positive lamp tap is made

on the generator side of the modifying coil, which means that no lamp current flows through that coil.

This is further illustrated in Fig. 223. The path of the lamp current is shown by dotted lines, while that of the battery is shown by heavy lines. When the links are to the left, and connected to terminals "A" as shown in Fig. 224, the positive side of the lamps is connected to the battery side of the modifying coil so that both lamp and battery current flows through the coil.

The potential coil of the regulator solenoid has four settings; a movable weight is hung from the lever arm and may be fixed

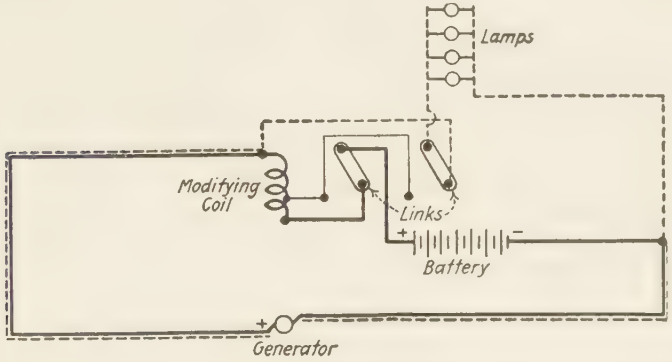


Fig. 223—Schematic Wiring Diagram of Main Circuits. Links to right for battery current regulation. Heavy lines show path of charging current from generator through modifying coil, link and battery, back to generator. The path of the lamp current is shown by dotted lines. Note that the lamp current is direct from generator to lamps and does not pass through modifying coil.

at any one of the four points as shown in Fig. 222. The four settings, reading from the left, are 47, 45, 43 and 40 volts respectively.

When this equipment is used with the type A-4-H, 150 A. H. Edison battery, the weight is set for 43, 45 or 47 volts regulation according to the season of the year. The setting when used with lead battery is 40 volts.

The automatic switch adjustment is the same as described for Type "C" equipment. The field carbon pile contains the proper amount of carbon discs when the distance from the top of the solenoid frame, with dashpot removed, to the top of the plunger

—not the tail rod—measures 2⅞ in. The regulator tension spring C is adjusted at the factory and the movement of the movable weight B from one point to another should give the correct setting. However, should it be necessary, the voltage setting may be adjusted as follows: With the generator operating and the weight B in one of the four positions, hold the automatic

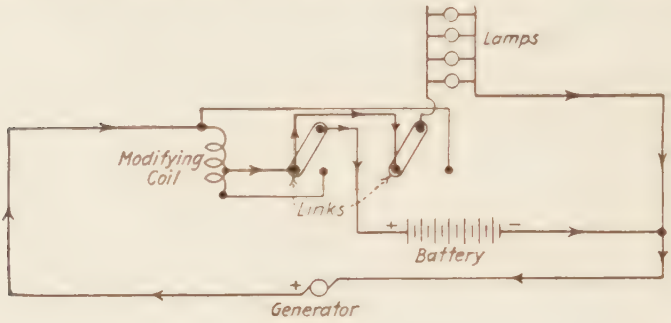


FIG. 224—Schematic Wiring Diagram of Main Circuits. Links in left hand position for generator current regulation. Current to battery and lamps shown by areas.

switch open and adjust the tension of the spring C until the regulated open circuit voltage is approximately 5.5 volts above the operating voltage setting, with the regulator coils hot. For example, to adjust the operating voltage to 43, adjust the open circuit voltage, with the regulator coils hot, to approximately 48.5 volts.

CHAPTER XXI

DIRECT-DRIVE EQUIPMENT FOR AXLE GENERATORS

The difficulties encountered in properly maintaining belts on axle generator equipment has resulted in many experiments having been made in an effort to design an efficient type of positive or direct drive. While this type of apparatus has not yet been developed satisfactorily and is not used in actual service, there has been considerable progress made.

This form of equipment has been considered by a committee of "Investigation to Determine the Merits of Direct Driving Axle Generators for Passenger Cars," appointed by the Association of Railway Electrical Engineers. An abstract of the report of this committee, presented in 1920, follows:

The advantages of such a form of drive are: Decreased liability of failure of drive, resulting in: Decreased liability of failure of light; less deterioration of battery—under-charging of battery on account of the belt slipping, and sulphating because of the battery becoming discharged and standing in that condition.

Decreased liability of having train detentions; less liability of annoyance to passengers, from flickering of lights caused by belt slipping; and no failure of lights due to loss of belt.

Positive drive under all conditions of weather; elimination of belt tension devices; simplification of suspension with consequent reduction in first cost and cost of maintenance of these parts of the equipment.

The disadvantages of such a form of drive are: Increase in first cost of drive and in cost of application; increase in length of time of train detention when drive fails; and difficulty in testing generator by motoring.

To be really successful, the direct drive should, in addition to its advantages over the belt drive, be capable of being operated

at a total cost comparable with the cost of operating the belt drive.

As a matter of information as to the present stage of development in this class of equipment, various designs of direct drive are here described briefly.

The "Bliss" Drive commonly known as the "hollow shaft drive"—consists essentially of the following points:

1. A split double dog clamped to the axle.
2. A split hollow shaft surrounding the axle, journaled in roller bearings, whose outer race was machined in an extension of the generator frame, and carrying two diametrically opposite arms at one end.
3. Four, open-wound helical springs, each spring being fitted with a casting at one end. These castings end in a ball fitting in spherical sockets located in the arms of the dog and in the arms of the hollow shaft.
4. A gear mounted on the hollow shaft meshing with—
5. A pinion mounted on the armature shaft.

The springs when applied were neither extended nor compressed, so that, for one direction of rotation, one pair were in compression and the other pair in tension. Reversing the direction of rotation placed the first pair in tension and the second pair in compression.

Considered solely as a means of transmitting power from the car axle, the drive was successful and the equipment as a whole operated satisfactorily for some time, but was removed on account of wear in the outer race.

As one-half of this race was machined in the same castings as one-half of the field frame, renewing the one meant renewing the other, and the expense involved was greater than was thought justifiable.

With this type of drive, no matter what the movement of the axle may be, only rotation is transmitted to the hollow shaft; a special axle is not required.

The "Deutsch" Drive consists of a split bevel gear, mounted on the axle, meshing with a bevel pinion mounted on a shaft and carried in a split gear box surrounding both gear and pinion. The gear box was prevented from turning by a vertical member that was attached to the truck frame. The axle was turned for

a bearing for the gear box, one bearing seat only being provided. The gear was clamped to the axle by means of four bolts.

The shaft carrying the pinion had, on its outboard end, one portion of a universal joint. The other portion was carried on an extension shaft provided with a feather key, while on the other end of this shaft was a portion of a second universal joint which connected to the other part of same mounted on the end of the armature shaft.

This drive was in service on Canadian Pacific Sleeper "Narbome" and on about ten cars of the Grand Trunk and Intercolonial Railways and one car on the Lake Shore & Michigan Southern. It did not give satisfaction, the trouble being ascribed to the fundamental mistake of providing only one bearing for the gear case and pinion support instead of two, and to the poor lubrication obtained, especially during cold weather. The result was that the gear and pinion tended to become unmeshed, ending finally in the destruction of the pinion.

These drives were in service in 1906 or 1907 and the best results were obtained on the L. S. & M. S. where 7,000 miles were obtained before the transmission required new bearing bushings and pinions.

The "Fitz" Drive has the armature built on a hollow spider having a bore sufficient to easily slip over the largest diameter of axle. This bore is enlarged in places for a short distance at each end, thus providing radial pockets in which helical springs under compression are placed, one end of the spring bearing on the circumference of the enlarged bore, the other, through a steel shoe, on the circumference of the axle.

Projections on the armature spider pass through the opening between the two halves of a driving dog clamped on the axle. Motion is, therefore, transmitted from the axle to the armature through the joint action of the driving dog and the helical springs. The dog also serves to retain the helical springs in the pockets.

With this construction, the armature being practically rigidly connected to the axle, the armature and field frame must move with the axle, partaking of all its motions.

The "Gould" Shaft-Drive requires the use of a special truck axle. A circular key ½ in. wide and ¼ in. high is machined on the axle midway between the two bearing fits 4½ in. long. A

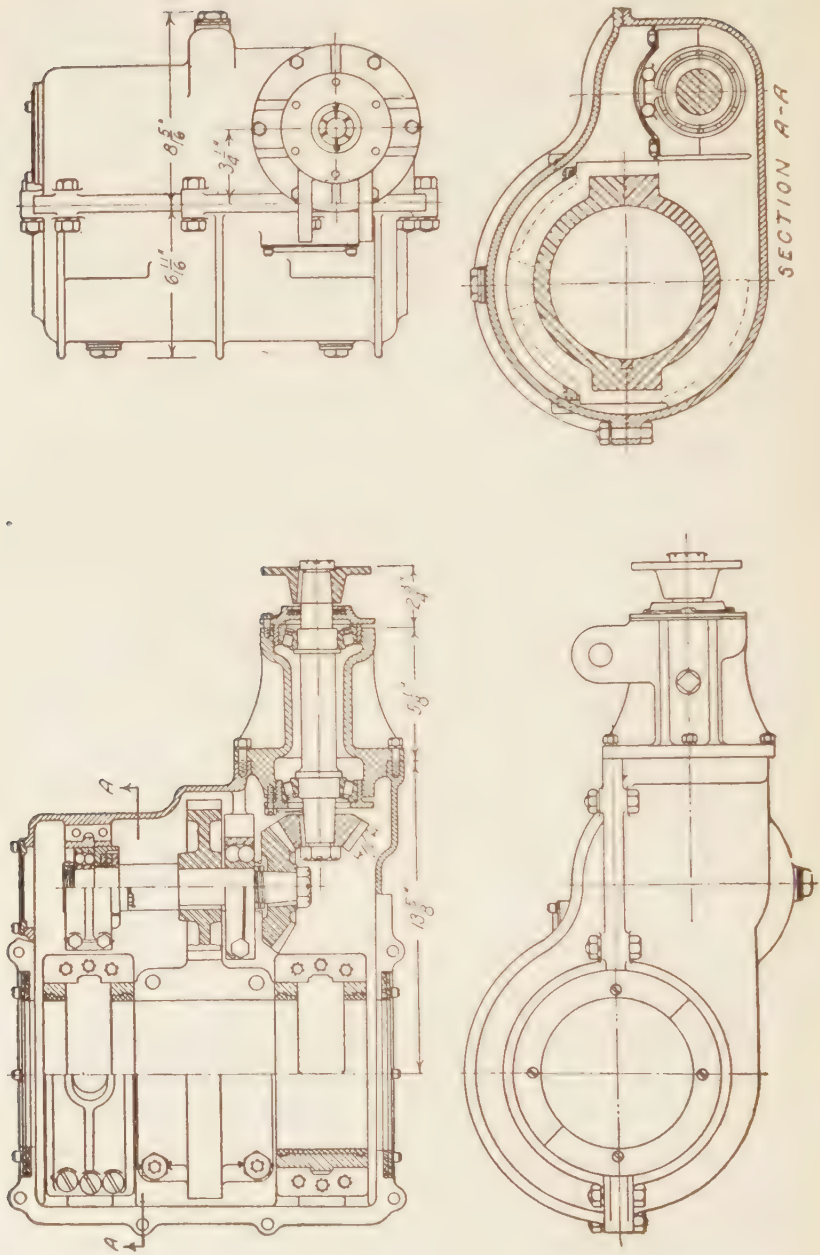


Fig. 225—Assembly Drawing of Main Part of Gould Shaft Type Direct Drive.

second key ½ in. by ½ in. and 5¼ in. long is fitted in the keyway cut in the axle parallel with its axis. The first key acts to center the split gear on the axle and the second serves to drive the gear. The bearing fits on the axle serve as a seat for the gear box.

A 52-tooth spur gear mounted on the axle meshes with a 36-tooth spur pinion mounted on a shaft, which is parallel to the axle in the gear box and is carried on ball bearings. On this shaft is a 28-tooth bevel gear, meshing with a 20-tooth bevel pinion on a second shaft perpendicular to the axle; this second shaft serves to drive the gear. The bearing fits on the axle and at the outboard end carries one part of a universal coupling.

The gear box is spit on the horizontal diameter of the axle and is prevented from turning by a member which connects the end of the gear box to the end frame of the truck.

A telescoping shaft, carrying on one end part of the first universal joint and on the other end a portion of a second universal joint, serves to transmit the power to the armature shaft.

Mounted on the armature shaft is a safety device consisting of a coupling carrying a shear pin so that if the generator becomes damaged in any way that will throw an excessive load on the drive, this pin will shear, permitting the drive to run free. This safety device also forms the second universal coupling. Disconnecting this safety device permits the generator to be operated as a motor for testing purposes.

The generator is mounted rigidly on the under frame of the car body with the armature shaft parallel with the longitudinal axis of the car.

Provision is made whereby the position of the bevel pinion can be adjusted so as to maintain the pitch lines of the bevel gears and pinion in contact.

The "Gould" Chain-Drive consisted of a split hub which was centered on the car axle by means of set screws, the space between the axle and interior of the hub being filled with babbitt, and clamped by bolts to the axle. A split sprocket shrouded on the outside was then mounted on and keyed to this hub.

The armature sprocket was somewhat similar in construction except that it was not split. Connection was made between the two sprockets by a Morse Silent Chain.

This drive was in service on several roads and gave excellent

service. It was found, however, that it was impossible to operate it satisfactorily, using a new chain with old sprockets, or vice versa, so that when one part wore out it was necessary to renew all parts.

The armature sprocket would require renewals after about 100,000 miles service, and the expense of operation did not make it an economical proposition as compared with a belt, and therefore the use of this drive was abandoned.

The "Matthews" Drive consists of a split spur gear clamped to the axle by means of tapered wedges, drawn together with bolts as to act as an expanding bushing.

This gear meshes with four shrouded spur pinions mounted on short shafts parallel to the axle. Three of these shafts run idle, the fourth carries a bevel gear which meshes with a bevel pinion mounted on a shaft perpendicular to the axle.

This second shaft is connected by means of a universal joint to an extension shaft provided with a sliding joint, and this in turn is connected to the armature shaft by a second universal joint.

The housing is at once cushioned and prevented from turning by a connection to the truck frame, the two portions of which are connected together through a helical spring, so arranged as to constrain the movement of the housing for both directions of rotation. So far as is known, this drive has never been tried out in service.

The Matthews-Aves Drive is an improvement on the original "Matthews" drive. This drive consists of a spur gear, a pinion, 3 spools or rollers, an expanding bushing consisting of 8 plugs and bolts, and a casing. The casing serves to support the pinion and rollers and to prevent dust and other foreign substances from entering the gears. It also holds the oil for lubricating the several parts. The pinion is preferably made of rawhide in order to facilitate quiet running.

A feature of this drive is its compactness, simplicity, and the ease of applying to the axle. The spools have a beveled flange which fits the beveled ledge or runway on the large gear, thus keeping the device in alignment and also keeping the pinion in mesh with the large gear. The gear is fixed to the axle by means of the taper plug and bolts which are cut away at one point to allow the bolts to be easily slipped through and fastened. The

spools and pinion are fixed to the casing by means of ball bearings. The shaft of the pinion projects at one or both sides, and to this projection is attached the shaft that drives the generator, connected by means of bevel gears or otherwise. The shaft connecting the drive with the generator, may consist of two universal joints, a flexible coupling and a friction joint, the friction joint permitting a certain amount of "slip" between the generator shaft and the driving device.

The "Pitt" Drive consists of a split spur gear bolted to the car axle, over which a layer of felt packing has been laid. This spur gear meshes with a spur pinion mounted on a shaft parallel with the car axle. On this same shaft is mounted a bevel gear meshing with a bevel pinion mounted on a second shaft, perpendicular to the car axle, and carrying at its outboard end one portion of a universal coupling, by which connection is made to a telescopic shaft which carries on one end the other part of the universal coupling, and at the other end one part of a second universal coupling, the remainder of the second universal coupling being secured to the armature shaft.

Both sets of gears and pinions are enclosed in a split housing. The housing is restrained in the horizontal plane by a cross-head through which the shaft passes, this cross-head being carried by a "U" frame attached to the truck frame.

The housing is, however, free to move, within limits, in a vertical plane, it being at once supported and prevented from turning by an inverted "U" frame, this frame being cushioned by two helical springs through which the supporting bolt passes, placed above and below the cross part of the "U" frame.

This supporting bolt, at its upper end, carries a short shaft on which are mounted two rollers, these rollers moving on two tracks which are formed in a casting secured to the underside of the car body.

So far as is known this drive has never been placed in service.

The "Safety" direct-drive consists of two axle bushings, mounted on the axle a little distance inside the wheel fit. Each bushing carries a collar to which eye bolts are secured; the eye bolts are connected by means of a helical spring, normally under tension, to a lug on a hollow shaft, the springs being approximately parallel with the longitudinal axis of the axle. This

hollow shaft has a sufficient internal diameter to permit the axle to move freely without fouling the shaft. The shaft is split and is supported at each end by the outer race-ways of four ball

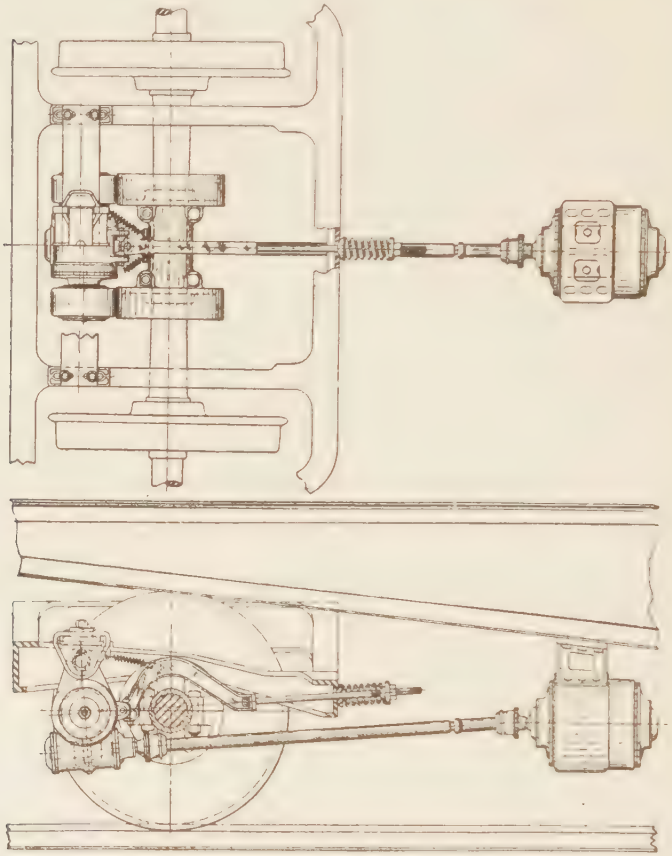


FIG. 226—Plan and Side Elevation of "U. S. L." Direct Drive.

bearings, the inner raceways of which are mounted on short shafts carried by the gear housing.

The gear housing is split and is carried on seats turned on each end of the hollow shaft, and is prevented from turning by lugs attached to cross bars fastened to the axle generator suspension irons.

Mounted on the hollow shaft is a split gear meshing with a

pinion which is mounted on a short shaft parallel to the axle and carried on ball bearings.

Mounted upon this short shaft is a bevel gear meshing with a pinion mounted on a second shaft, which also is carried on ball bearings and is perpendicular to the axle of the truck.

This second shaft is connected to the armature shaft by means of a split coupling, no universal joints being provided, as the generator is carried on suspension irons attached to the truck frame.

This drive does not require a special axle; no provision has been made for maintaining the pitch circles of the bevel gear and pinion in contact. This drive has never been used in actual service.

The "U. S. L." Drive consists of a 17-in. split steel pulley secured to a standard car truck axle by means of through bolts.

These pulleys drive, by contact, two 10-in. pulleys or friction wheels which are made of rubber tires moulded on steel rims, the rims being pressed on the center hub of the pulley; the tires are similar to the standard tire as ordinarily used on industrial automobile trucks.

The pulleys are mounted on the ends of a short shaft, parallel to the axle, this shaft being supported by two sets of ball bearings which are carried from housing pivoting about a horizontal cylindrical bar in a position approximately vertically above the pulley shaft.

The bar is supported by a steel casting mounted on a member which is supported by the truck frame; the casting is arranged so that it will pivot in a horizontal plane around a bolt, equalizing the pressure of the friction wheels on the pulleys.

At the center of the shaft carrying the friction wheels, a worm wheel is mounted which meshes with a worm mounted on a second shaft perpendicular to the axle. The second shaft is also carried on the ball bearings which are mounted in a casting bolted to the casting forming the housing for the worm wheel.

This second shaft is connected by means of a universal joint to an extension shaft provided with a sliding joint, and this in turn is connected to the armature shaft by a second universal joint.

The worm shaft is connected to the shaft of the axle generator, which is mounted longitudinally under the car body by means of

two universal couplings and an extension shaft with a sliding joint.

Pressure between the pulleys and friction wheels is assured by a bar, attached to the housing midway between the pulley, curved so as to pass over the axle. The bar extends beyond the end sill of the truck and has a thread cut on the end. Beyond the truck frame the bar passes through a helical spring and the pressure between the pulley and friction wheel is adjusted by the amount of compression that takes place in this spring.

This drive has been operating for some time in experimental service in the shop but has not been used in actual train service.

APPENDIX

AMERICAN RAILWAY ASSOCIATION

STANDARDS AND RECOMMENDED PRACTICES

The development of electric lighting equipment for railway cars has been closely followed by the Mechanical Division of the American Railway Association and various Standards and Recommended Practices have been adopted. A brief historical record of the adoption and revision of these practices follows:

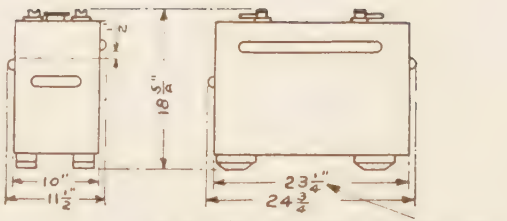
Train Lighting.—Recommended Practice. In 1912 "Specifications for the Electric Lighting of Passenger Equipment Cars" were adopted, as Recommended Practice, by the Master Car Builders' Association. These specifications were revised by the Master Car Builders' in 1913, 1914, 1917 and 1918.

In 1919, 1920 and 1922, the Mechanical Division of the American Railway Association—a consolidation of the former Master Car Builders' Association and the Railway Master Mechanics' Association—made further revisions.

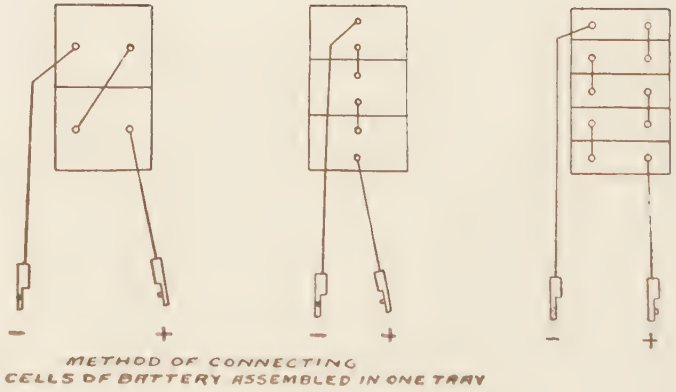
Train Lighting.—Standard. Parts of the specifications which had been adopted in 1912 as "Recommended Practice" were revised in 1913, 1914, 1915 and 1916. With further revisions in 1917, these specifications were advanced to "Standard"; these standards were revised in 1919 and 1920.

Specification for Axle Generators.—Recommended Practice. In 1920 "Specifications for Axle Generators" were adopted by the Mechanical Division as Recommended Practice. These specifications were revised in 1922.

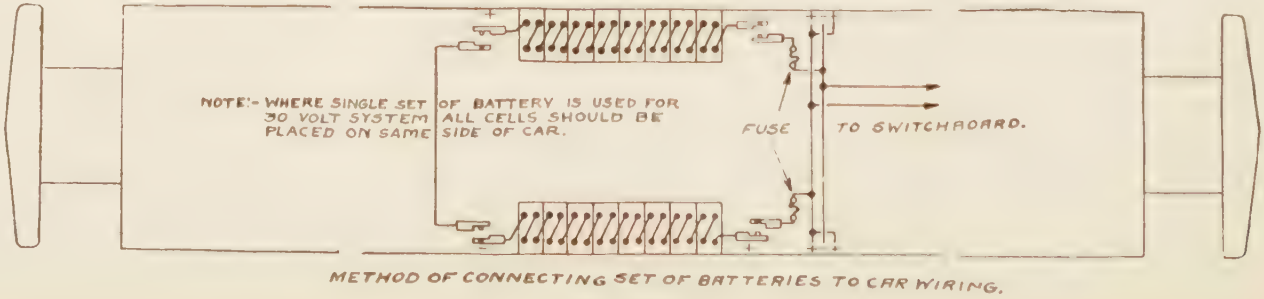
A topical discussion on the progress made and the state of the art of car lighting will be found in the 1902 M. C. B. Proceedings, page 312. Other reports will be found in the 1903 Proceedings,



A. R. A. Fig. 1.



A. R. A. Fig. 2.


NOTE:- WHERE SINGLE SET OF BATTERY IS USED FOR 30 VOLT SYSTEM ALL CELLS SHOULD BE PLACED ON SAME SIDE OF CAR.
FUSE
TO SWITCHBOARD.
METHOD OF CONNECTING SET OF BATTERIES TO CAR WIRING.

A. R. A. Fig. 3.

page 294; 1910 Proceedings, page 484; 1911 Proceedings, page 338.

The present A. R. A. Standards and Recommended Practices are as follows:

ELECTRIC TRAIN-LIGHTING

Standard—ADOPTED, 1917; REVISED, 1920.

I. General.

1. *System Voltages.*—(a) In electrically lighted cars the following voltages should be used:

(b) Sixty volts (nominal) for straight storage and head-end systems.

(c) Thirty volts (nominal) for straight storage and axle-generator systems. (Individual cars.)

II. Generator.

5. *Mounting.*—When facing the end of the truck on which the axle pulley is mounted, the generator pulley or sprocket shall preferably be on the right of the generator.

6. *Axle Pulley and Bushing.*—(a) A straight pulley seat shall be provided for the axle pulley.

(b) If a bushing be used, it shall preferably be secured to the axle independently of the pulley; have an external diameter throughout its length of 7½ in.; and be not less than 8½ in. long.

(c) The hub of the axle pulley shall have a uniform internal diameter of 7½ in.; the length of the hub shall be 6½ in.

(d) The diameter of the axle pulley shall be as large as the construction of the car will permit, preferably 21 in. or 17 in.

9. *Size of Ball-bearings.*—On all truck-supported, ball-bearing axle generators the bearing shall be of the size known commercially as No. 412.

III. Batteries.

10. *Design of Battery Boxes.*—(a) Battery boxes shall have interior dimensions at least as great as given below:

Height in clear, 21½ in. Depth, front to back, 2 ft. 1 in.

Length of compartment to hold two standard double compartment trays, 22⅝ in.

Length of compartment to hold four standard double compartment trays, 3 ft. 9¼ in.

(b) Battery boxes with two compartments, each 22⅝ in. long, or with one compartment 3 ft. 9¼ in. long, shall be designed to carry a battery weight of not less than 1600 lb.

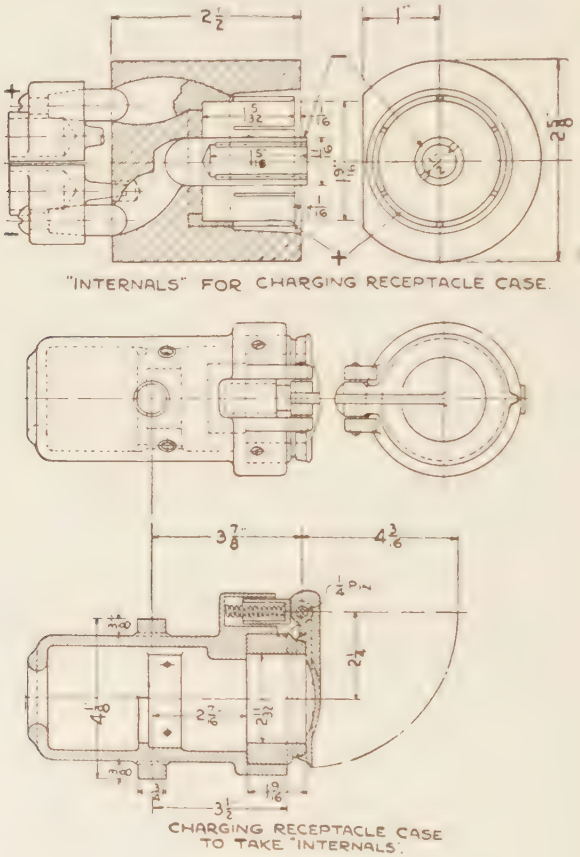
(c) Battery boxes with four compartments, each 22⅝ in. long, or two compartments, each 3 ft. 9¼ in. long, shall be designed to carry a battery weight of not less than 3200 lb.

(d) In all battery-box designs two angle irons or straps shall extend longitudinally under the battery box and shall be located so that in case of a defective battery-box floor the trays will be supported by the said angle irons or straps. The angle irons or straps shall be attached to the car body independently of the battery box and shall be of sufficient strength in all parts to safely support the weight of battery as given in paragraph 10 (b) and (c); plus the weight of the battery box. The angle irons or straps shall be so installed that they can be readily inspected. A construction equal to the above in strength and safety will be allowed.

12. *Trays.*—Storage batteries for car-lighting service shall be assembled

in trays whose maximum dimensions shall not exceed those given in A. R. A. Fig. 1 when used in a battery box having minimum dimensions given in paragraph 10 (a).

13. *Connections.*—(a) Where two or more cells are assembled in one tray, the connections and arrangements of battery terminals shall be as in A. R. A. Fig. 2.



A. R. A. Fig. 4.

(b) The connections between the terminals of the battery and car wiring shall be made with a connection as shown in A. R. A. Fig. 3.

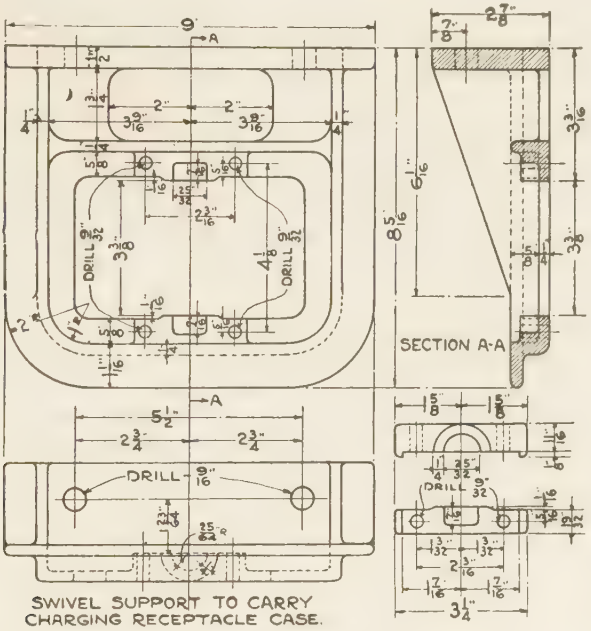
(c) When the Westinghouse type connector is used to connect battery to car wiring, it shall be installed as follows: At the positive terminal of the battery the male end of the connector shall be attached to the positive battery terminal lead and the female end to the car wiring. At the negative terminal of the battery the reverse connections shall be made.

(d) Each set of batteries shall be connected so that, facing the battery box, the positive terminal is at right, as shown in A. R. A. Fig. 3.

14. *Charging Receptacles for Batteries.*—(a) Each electrically lighted car equipped with batteries shall be provided with two charging receptacles, as shown in A. R. A. Fig. 4 so as to receive plug shown in A. R. A. Fig. 6.

(b) These receptacles shall have swivel supports, as shown in A. R. A. Fig. 5.

(c) These swivel supports shall be installed one on each side of the car as shown in A. R. A. Figs. 3 and 7.



A. R. A. Fig. 5.

(d) The outer annular contact shall be connected to the positive terminal of the battery, as shown in A. R. A. Figs. 3 and 4.

VI. Wiring.

16. *Terminals, Arrangements and Identification.*—(a) The terminal connections of the generating, regulating and controlling apparatus shall be marked for identification and polarity.

(b) The positive terminals shall be at the right, when facing the board (if terminals are arranged horizontally) and at the top (if arranged vertically).

19. *Switchboards.*—(a) Each electricaly lighted car shall be provided with a switchboard, upon which shall be mounted the necessary switches, fuse contacts and terminal connections.

(b) The switches and terminal connections shall be arranged so as to

disconnect (when opened), and the fuses to protect the following parts, if same be used:

(1) Train line. (2) Battery. (3) Axle generator. (4) Main light switch or fuses. (5) Circuit for lamps, fans, etc.

(c) Each of the above switches or fuse contacts shall be plainly marked, designating the part controlled or protected.

(d) The terminals for the axle generator at the generator regulator panel shall be arranged so that, when open, they shall disconnect the positive and negative armatures and one side of the field circuit.

20. *Fuses for Wiring, Etc.*—(a) The switchboards or regulator panels of electrically lighted cars shall be provided with fuses for protection of parts given below:

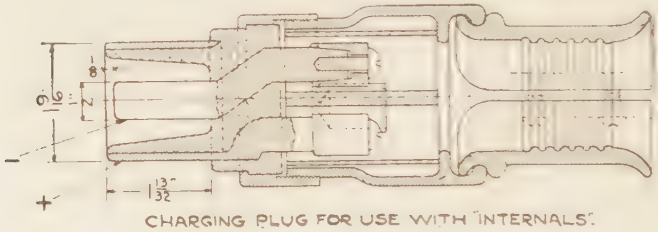
(1) *Train Line.*—Contacts for use with open link fuses shall be provided substantially as shown in A. R. A. Fig. 9. the stud or screw to be ¼ in. in diameter, with twenty threads per in. set on 2½-in. centers.

(2) *Battery.*—Use of fuse optional. If fuse be used, the fuse and fuse contacts shall be same as for train line.

(3) *Main Light Switch.*—Use of fuse optional. If fuse be used, the fuse and fuse contacts shall be the same as for train line.

(4) *Circuits.*—For the distribution circuits to the lamps, fans, etc., the fuse and fuse receptacle shall be of the Edison screw-shell type of fuse, as shown in A. R. A. Figs. 10 and 11.

(5) *Axle Generator.*—The positive armature to have fuse contacts suitable for a 150-ampere knife-blade, National Electrical Code fuse, with a



A. R. A. Fig. 6.

4-in. clearance space between contacts as shown in A. R. A. Fig. 12. The fuse holder to receive link fuse is shown in A. R. A. Fig. 26.

(6) The use of a fuse in the field circuit is optional. If used, the contacts shall be suitable for a 0 to 30 ampere, ferrule type, National Electrical Code fuse, with 1 in. clear space between contacts as shown in A. R. A. Fig. 14.

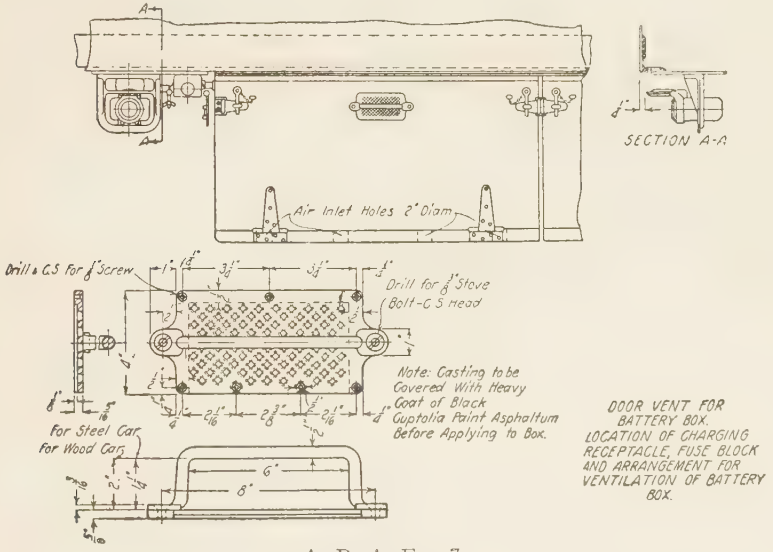
(b) All fuses on cars shall be used in the location and shall conform to the dimensions as shown in A. R. A. Figs. 8, 10, and 13.

(c) The capacity of the fuses used in the above contacts shall be such as to properly protect the apparatus.

21. *Installation of Conduit and Wire.*—The following rules shall be used for car wiring:

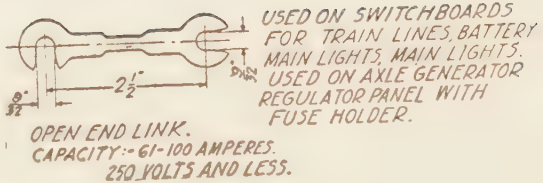
(a) *Conduit.*—All conduit shall conform to the requirements of the National Electrical Code, except that minimum size of ⅜ in. may be used. It shall, wherever possible, be run on the interior of the car, but not exposed to view. Ends of conduit shall be cut square and the interior reamed smooth, the contour of the material from the inner to the outer wall at the ends being approximately a quarter circle. Conduits shall

not "butt" in couplings. Where threads on conduit are exposed, they shall preferably be red or white leaded and painted. The conduit shall be of such size and so arranged that the wires may be pulled in after the car is completed and pulled out for repairs without it being necessary to remove the interior finish of the car. Conduit less than ⅜ in. shall not be used. Conduit and fittings shall be firmly and securely attached to the car body. The conduit system shall be so installed as to form a good, continuous electrical conductor and shall be grounded to the framework of the car. On steel or steel-underframe cars the supports of the conduit system will be considered as constituting an adequate ground. On wooden cars the conduit system shall be grounded by means of a copper wire of not less than No. 6 A. W. G., securely attached to the conduit and to some portion of the steelwork of the car that has an electrical connection with the rail, so as to form a good electrical connection at the point of attachment. The connections of the ground wire shall be exposed to view and easily accessible.

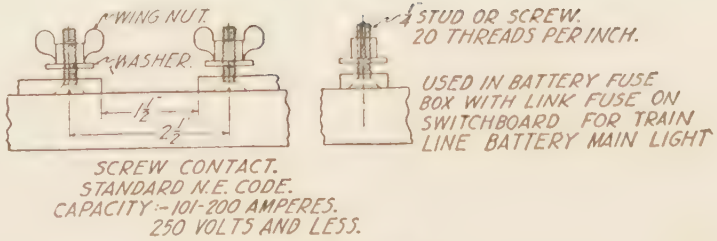

A
SECTION A-A
Air Inlet Holes 2" Diam.
Drill & C.S. for ⅜" Screw
Drill for ⅜" Stove Bolt-C.S. Head
Note: Casting to be Covered With Heavy Coat of Black Guptolia Paint Asphaltum Before Applying to Box.
For Steel Car
For Wood Car
DOOR VENT FOR BATTERY BOX.
LOCATION OF CHARGING RECEPTACLE, FUSE BLOCK AND ARRANGEMENT FOR VENTILATION OF BATTERY BOX.

A. R. A. Fig. 7.

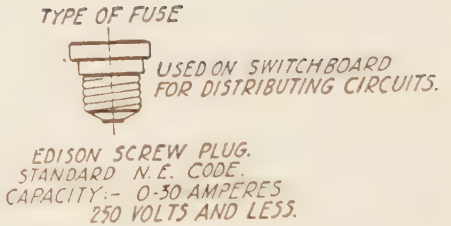
(b) *Fuse, Junction Boxes, Etc.*—Fuse, junction, outlet, connection and pull boxes exposed to the weather shall be of cast iron. The wall thickness at the bosses for the conduit shall be such as to insure that at least five threads of the conduit are engaged and that the interior of the boss be rounded off so as to provide the equivalent of an outlet bushing. "Knock-out" boxes of pressed or formed steel may be used when not exposed to the weather, and, when used, lock-nuts shall be used on the conduit on both sides of the box wall and an outlet bushing on the end of the conduit. "Pull" boxes shall be installed where, on account of the length of run or number of bends, it would otherwise be difficult to pull in the wires. Fuse boxes for the main battery fuses shall be installed as close to the terminals of the battery, both positive and negative, as possible. All boxes shall be so installed as to render the covers of same



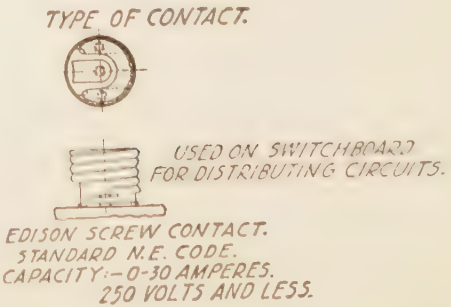
A. R. A. Fig. 8.



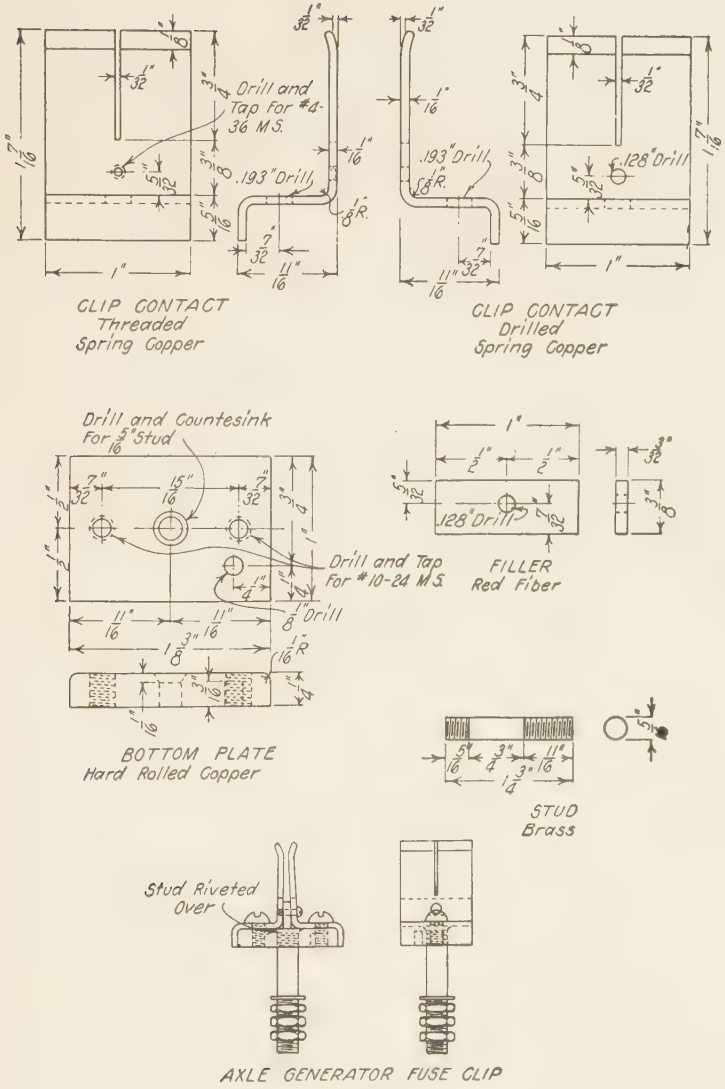
A. R. A. Fig. 9.



A. R. A. Fig. 10.



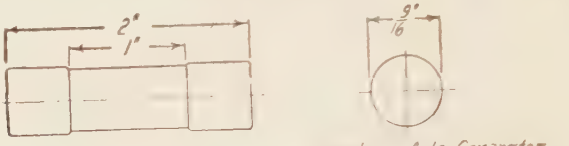
A. R. A. Fig. 11.


Drill and Tap For #4-36 M.S.
.193" Drill
.193" Drill
.128" Drill
CLIP CONTACT Threaded Spring Copper
CLIP CONTACT Drilled Spring Copper
Drill and Countersink For 5/16" Stud
Drill and Tap For #10-24 M.S.
1/8" Drill
.128" Drill
FILLER Red Fiber
BOTTOM PLATE Hard Rolled Copper
STUD Brass
Stud Riveted Over
AXLE GENERATOR FUSE CLIP

A. R. A. Fig. 12.

readily accessible. The covers of boxes exposed to the weather shall be applied in such a manner as to render the box weatherproof.

(c) *Wire.* All wires shall be insulated with Grade "A" (30 per cent Para rubber) insulation, if mineral base compound be used, according to the specifications of the Association of Railway Electrical Engineers, or equivalent, and shall be double braided; or if a wax base compound be used, it shall be of a corresponding quality. No wire smaller than No. 14 A. W. G. shall be used, except for fixture work, where No. 18 A. W. G. is permissible. All wires shall be run in metal conduit. No wire shall carry, under normal operating conditions, a current in excess of the



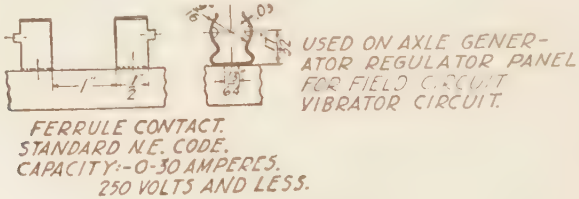
A. R. A. Fig. 13.

values permitted by the National Electric Code for the size of wire in question. Train line wires on cars intended for service on head-end system shall be No. 4/0 A. W. G. Train line wires on cars not intended for service on head-end system shall be No. 2 A. W. G. All wires of No. 8 or larger shall be stranded. Train line connection between cars shall be as follows:

Head-end System.—No. 2/0 A. W. G., 833 strands or more, 5/64 in. insulation and one braid.

Not for Head-end System.—No. 2 A. W. G., 133 strands or more, 4/64 in. insulation and one waterproof braid.

The leads from the generator to the terminal connector on the car body shall be as follows:



A. R. A. Fig. 14.

Armature and Field Leads.—No. 4 A. W. G., 61 strands, 4/64 in. insulation, two weatherproof braids.

(d) *Joints and Splices.*—The insulation shall be removed from the wire in such a manner that the wire shall not be cut, scored or nicked. All joints and splices shall be so made as to be both mechanically and electrically secure without the use of solder. All joints and splices shall be soldered; the soldering flux shall be free from acid. All wires joined or spliced shall be installed in such a manner that the joint or splices come in a junction box or fitting. Slack shall be left in wires at junction boxes and other outlets. Care should be taken that no sharp end of wire

or solder is left to pierce the insulation and cause a ground. The joint or splice shall be covered with a rubber tape to the thickness of the original insulation, and this covered with friction tape to the overall diameter of the complete insulated wire.

ELECTRIC TRAIN-LIGHTING

Recommended Practice—ADOPTED, 1912; REVISED, 1920.

I. General.

2. *Descriptive Notices.*—That each electrically lighted car in steam service shall be provided with a notice located in or near the switchboard locker as follows:

A. B. & C. Railroad

Description of Electric Light Equipment.
This car is lighted by ...:V.... System.

	Gen.	Gen. Reg.	Lamp Reg.
Make			
Type			
Set for volts—max.			
Set for V. floating			
Set for amps. batty			
Set for amps.—max.			

Pulleys.—Axle....in. dia....in. face; ....in. depth of flange.
Armature .... in. dia. .... in. face.
Belt.—Length .... ft. .... in.; Width .... in.
Battery.—No. cells on car ....; No. sets in parallel ....
Amp. hr. capacity each set at 8 hr. rate ....
Charging current each set .... normal, ... max.
Lamps.—Voltage. ....
Load.—Lights (including fans) ..... amps.
Battery ..... amps.
Total ..... amps.
Train Line Wires.—No. ..... (2 or 3). Size ..... A. W. G.

3. *Clearances.*—(a) The axle-generator suspension shall be so designed that with the car on level track the clearances shall be as great as possible, but not less than those specified below:

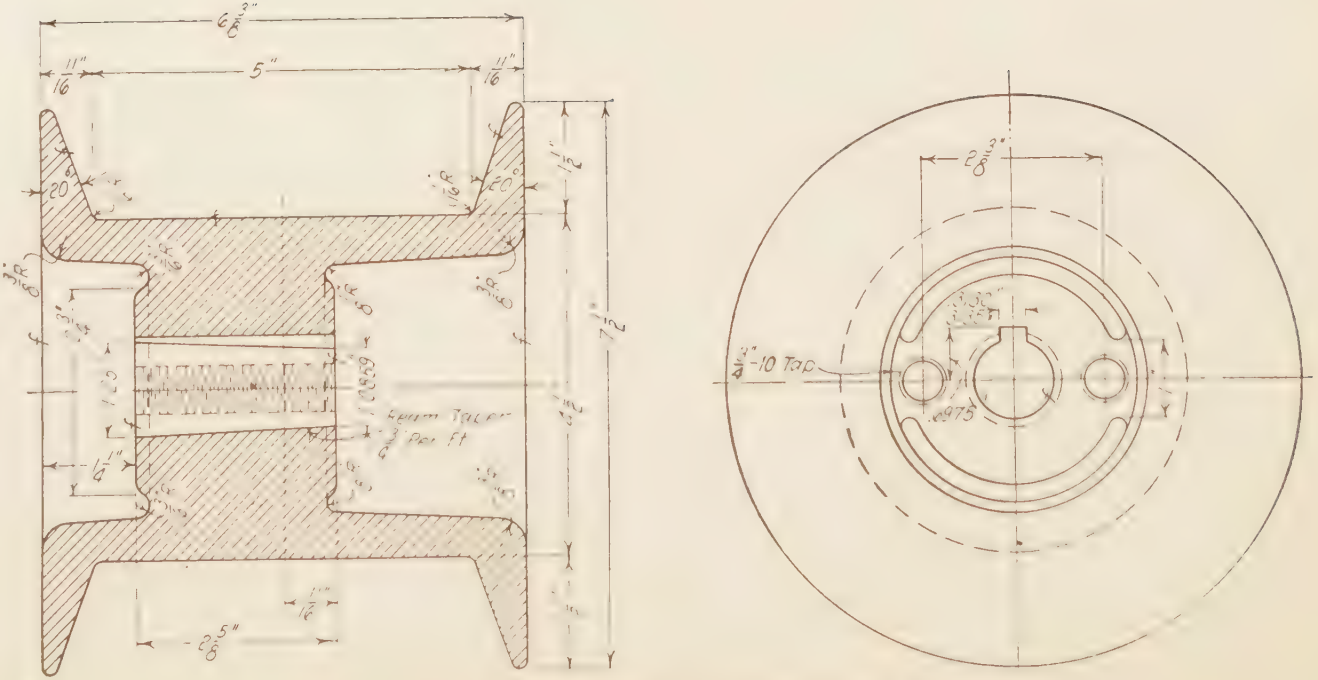
(b) From any part of the generator or suspension to the rail.....6 in.

(c) On truck-suspended generators, from any part of the generator or suspension to the car body or any part attached thereto.....3½ in.

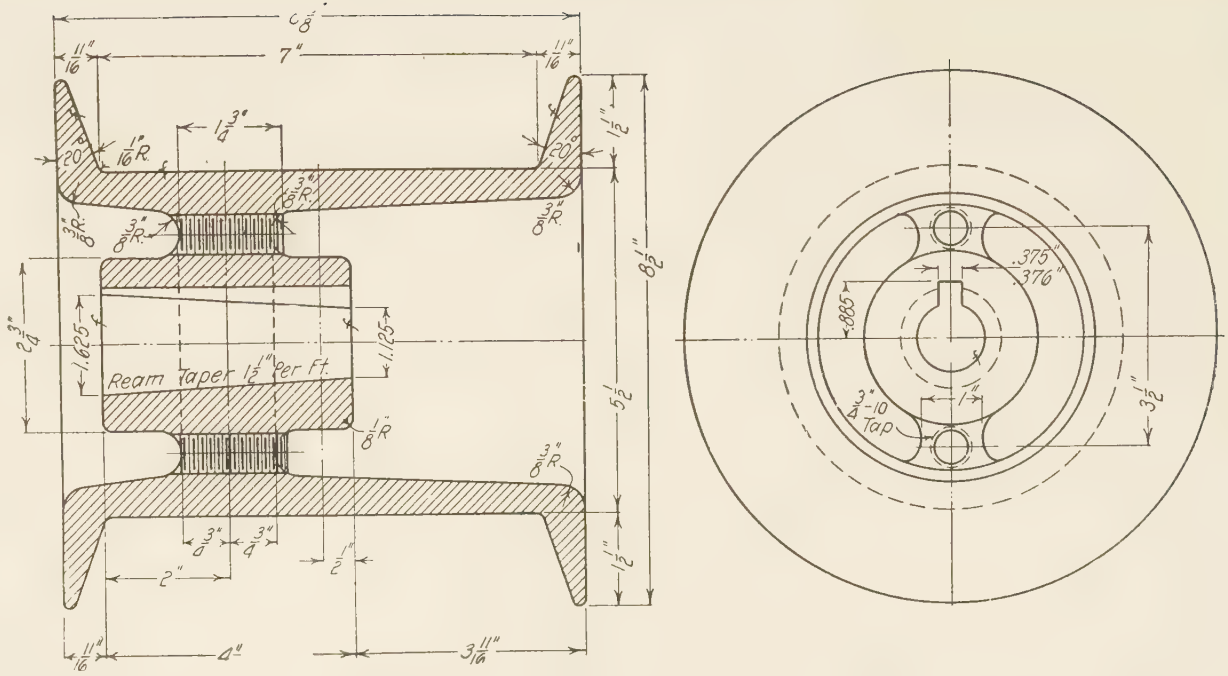
(d) With all parts of the car and axle generator, affecting the clearances, in the same condition as when new, with the minimum belt tension to drive load and with the generator in any service position with respect to the suspension and with the truck in any service position with respect to the car body, the clearance shall be from any part of the belt to:

	End Sill		Brk. Beam		To any other part car body or truck
	Over Inch	Under Inch	Over Inch	Under Inch	Inch
Truck Supported	1	1½	2½	1	½*
Body Supported	1½	1½	3	1	1

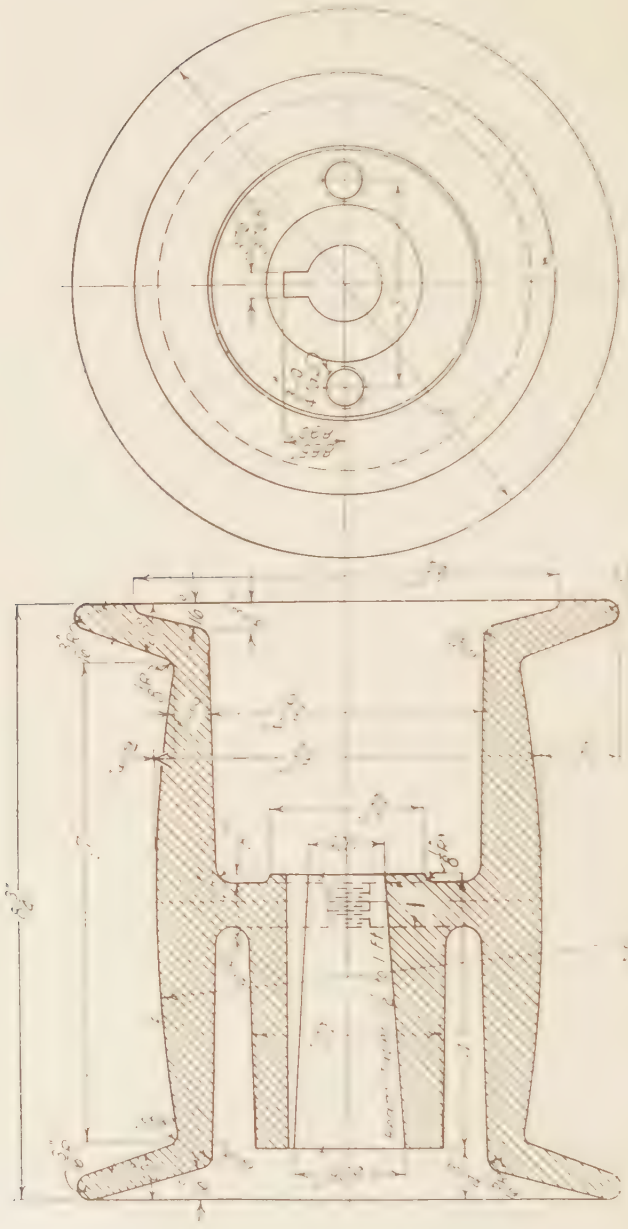
(e) With any or all parts of car and axle generator worn to the allow-



A. R. A. Fig. 15—4½-in. Pulley for Controlled-Speed Generator.



A. R. A. Fig. 16—5½-in. Pulley for Controlled-Speed Generator.



A. R. A. Fig. 17—5½-in. Pulley for Free-Speed Generator

able limits and other conditions the same as in paragraph (d), from the belt to any part of the truck or car body.....½ in.

NOTE: As the obtaining of the clearances specified in the preceding rule, is essentially a problem of car and truck design, it is recommended that all car designers pay special attention to this feature. The chairman of this committee has been instructed to take this matter up with the other A. R. A. committees interested.

II. Generator.

4. *Method of Testing to Determine Rating.*—(a) The generator, together with the generator and lamp regulator if used, shall be connected in a normal manner to dead load resistance in the battery and lamp circuit, and

(b) Shall be operated continuously for five hours, with commutator hand-hole covers removed, at the minimum r. p. m. that will generate rated volts at the load side of the generator regulator and carry the current, and that

(c) The net current output shall be the armature current less all current consumed in the generator fields, generator regulator, and lamp regulator, if used.

4-A. *Rating.*—(a) The rating of an axle generator, when connected and operated as above, shall be the maximum net current that the generator will carry without exceeding the following temperature values, measured by the thermometer method.

PART OF APPARATUS	Insulation A. I. E. E. Classification.			
	Class "A."		Class "B."	
	Maximum Observable Temperature Degrees C.	Maximum Observable Rise in Temperature Degrees C.	Maximum Observable Temperature Degrees C.	Maximum Observable Rise in Temperature Degrees C.
Any part of generator regulator, except resistance units, carbon piles, commutator, brushes, brush rigging and bare copper solenoids....	105	65	125	85
Commutator, brushes, brush rigging and bare copper solenoids.....	125	85	125	85

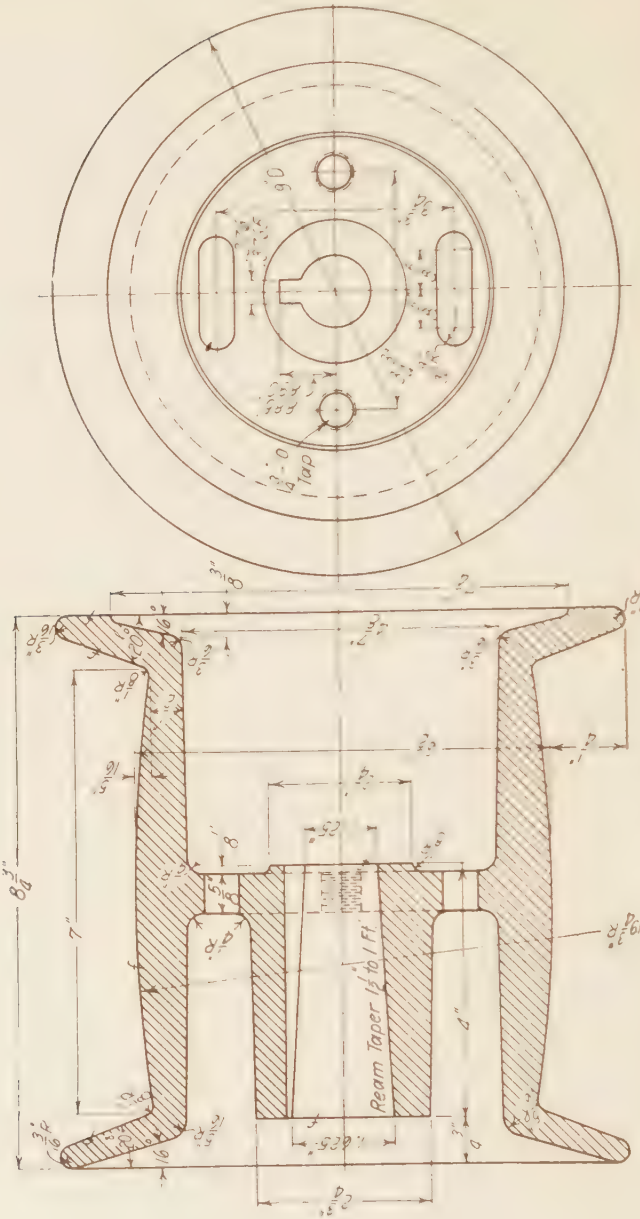
(d) *Bearings.*—Maximum observable temperature 65° C.

4-B. *Rating Test.*—The rating test shall be made at or above 15° C. ambient temperature.

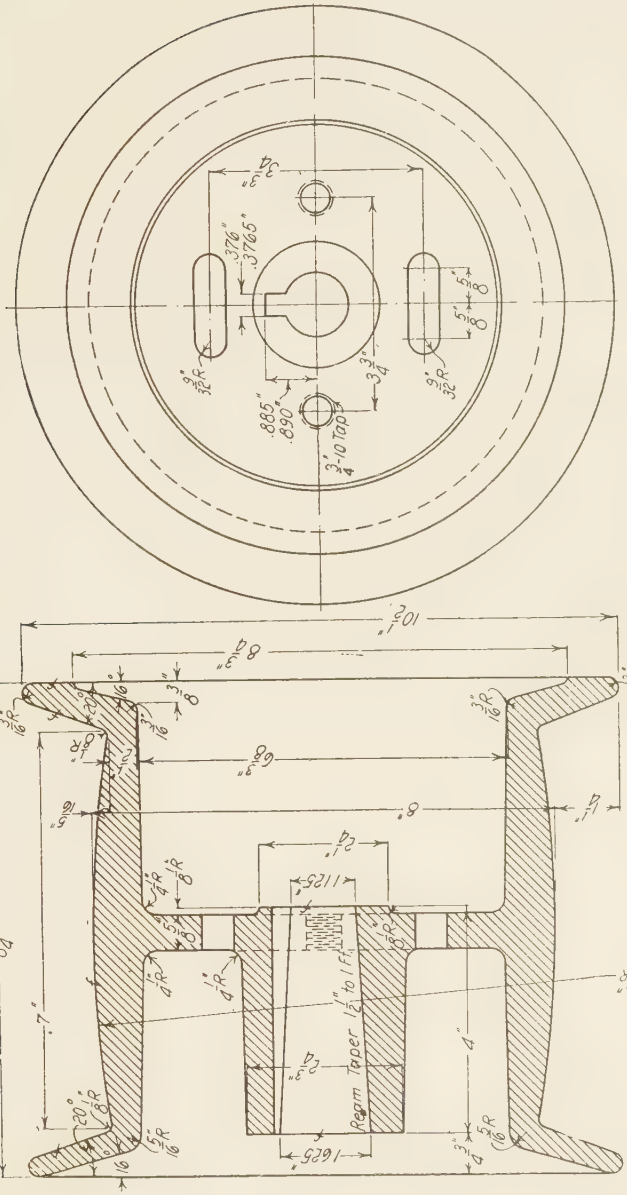
5. *Badge Plate.*—A badge plate shall be securely attached to each axle generator which shall show the following:

(a) Manufacturer's name.

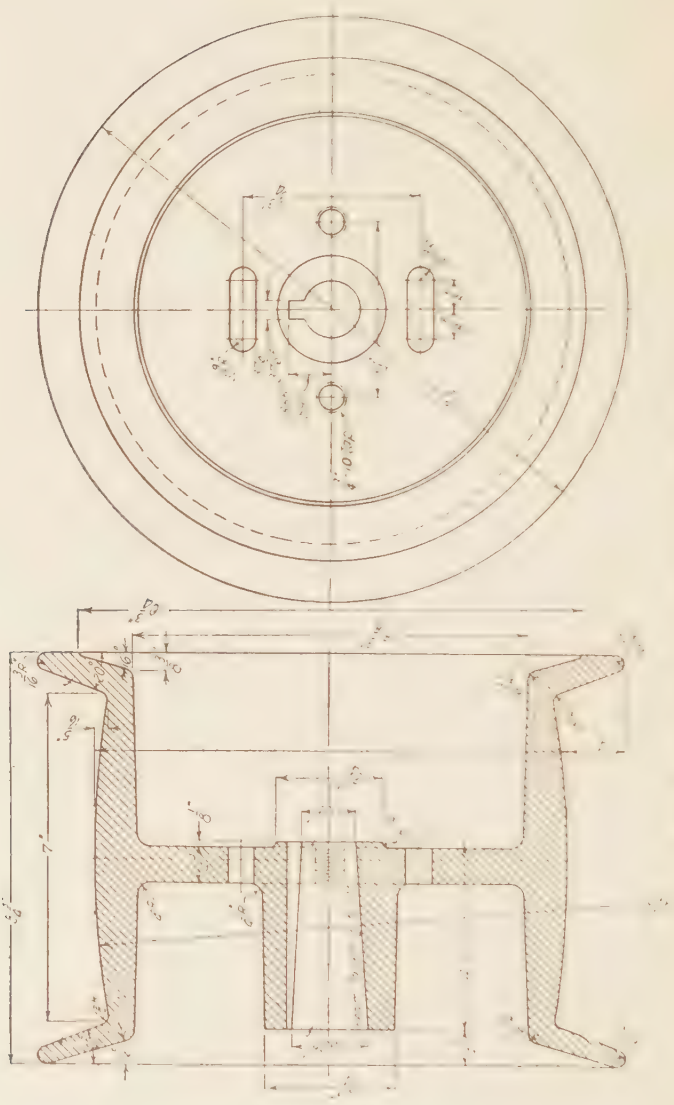
(b) Type number.



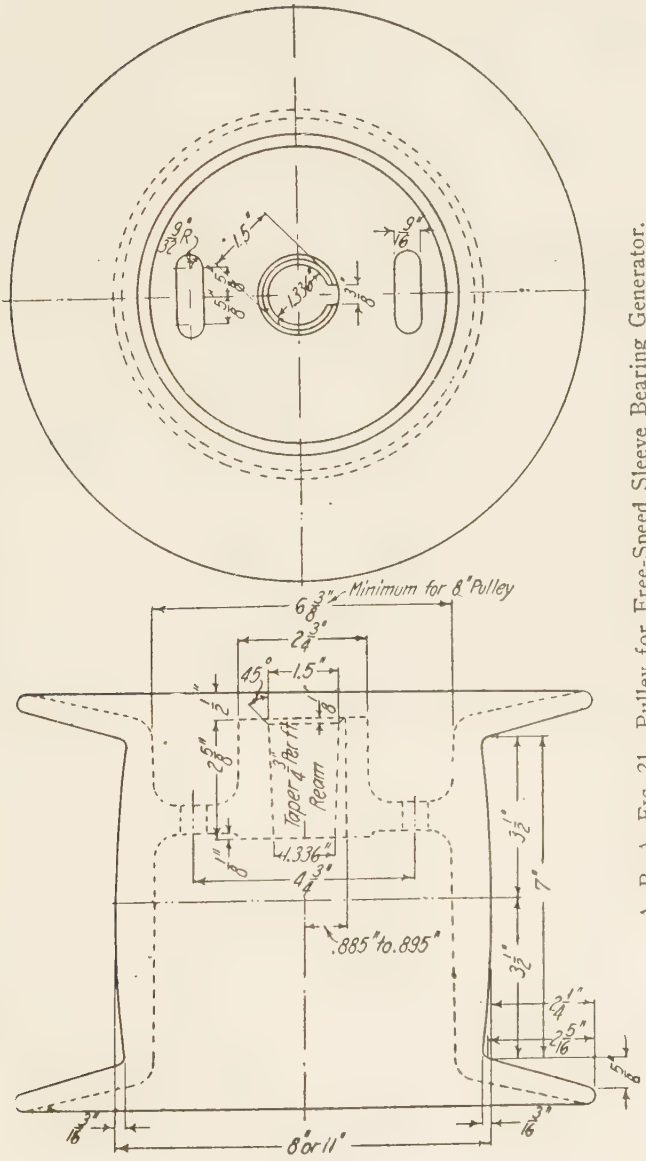
A. R. A. Fig. 18—6½ in. Pulley for Free Speed Generator.



A. R. A. Fig. 19—8-in. Pulley for Free-Speed Generator.



A. R. A. Fig. 20. 10 in. Pulley for Free Speed Generator.



A. R. A. Fig. 21—Pulley for Free-Speed Sleeve Bearing Generator.

(c) Nominal voltage of generator (40 volts for 30-volt system and 80 volts for 60-volt system).

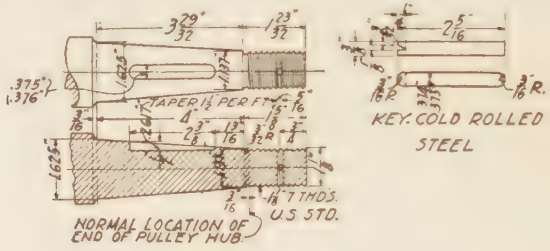
(d) Rating in amperes.

(e) Minimum full load speed in r. p. m.

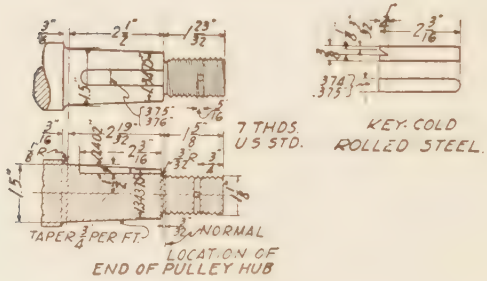
(f) Pulley ratio ——: ——.

6. *Suspensions.*—(a) In axle-generator suspensions, all supporting parts subject to wear shall have the wearing surfaces bushed.

(b) All axle generators shall be provided with safety chains or an equivalent construction which will safely support the generator in case of failure of the suspension.



A. R. A. Fig. 22



A. R. A. Fig. 23.

(c) In truck-supported axle generator suspensions, if side arms be used, the end to be secured to the truck frame shall extend under the transom and be secured to the side frame near the transom, and shall be securely attached to the end sill by a U-bolt not less than ¾ in. in diameter, or a construction equivalent in strength.

7. *Armature Pulley.*—(a) The armature pulley shall be flanged and crowned for "free speed" generators and flanged but not crowned for "controlled speed" generators.

(b) On all ball-bearing "free speed" axle generators, the armature pulley shall be in accordance with the dimensions as shown in A. R. A. Figs. 17, 18, 19, or 20.

(c) On all sleeve-bearing axle generators having armature pulleys 8 in. in diameter or larger, the armature pulley shall be in accordance with the dimensions as shown in A. R. A. Fig. 21.

(d) On all "controlled speed" axle generators, the armature pulley shall be in accordance with dimensions shown in A. R. A. Figs. 15 or 16.

8. *Armature Pulley Seat.*—(a) On all "free speed" ball-bearing axle

generators the pulley end of the armature shafts and key shall be in accordance with the dimensions as shown at "A" in A. R. A. Fig. 22.

(b) On all sleeve-bearing axle generators having armature pulleys 8 in. in diameter or larger, the pulley end of the armature shaft and key shall be in accordance with the dimensions as shown at "B" in A. R. A. Fig. 23.

(c) On all axle generators having armature shafts less than 1½ in. in diameter at end of pulley seat, the pulley end of armature shaft and key shall be in accordance with the dimensions shown at "C" in A. R. A. Fig. 24.

(d) Ball bearings used shall be of the annular ball type and of the size shown in the following table:

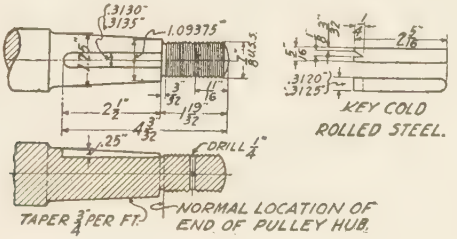
Truck Suspended.		BODY SUSPENDED. Width of Belt Required to Transmit Necessary Power.									
		Free Speed.						Controlled Speed.			
		5 In.		4 In.		3 In.		4 In.		3 In.	
Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.
412	412	412	*412	409	*409	407	407	312	312	307	3[illegible]
.....	.....	.....	‡409	.....	‡407	.....	.....	.....	‡308	.....	‡30[illegible]

*Preferred. ‡Alternate.

III. Batteries.

11. *Ventilation of Battery Boxes.*—(a) Each battery box shall be provided with adequate ventilation as follows:

(b) Inlet openings located on the longitudinal center line of the floor



A. R. A. Fig. 24.

of the battery box, having a combined area of approximately 6 sq. in. for each 22⅝-in. compartment.

(c) Outlet openings located near the top of the battery box, having a combined area of approximately 6 sq. in. for each 22⅝-in. compartment.

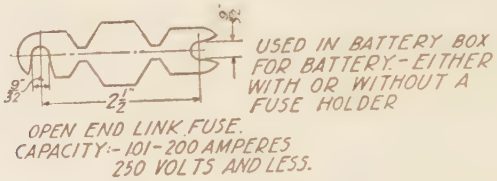
15. *Fuses for Batteries, Etc.*—(a) That each electrically lighted car equipped with battery box or boxes shall be provided with suitable metal fuse boxes, said boxes to be mounted close to the positive and negative terminals of each set of batteries, as shown in A. R. A. Figs. 3 and 7.

(c) The fuse block shall be provided with contacts (A. R. A. Fig. 27) (1) To receive a link fuse as shown in A. R. A. Fig. 25, (2) To receive

a standard National Electrical Code 150-ampere cartridge fuse, or (3) A fuse holder to receive a link fuse (designed to replace the N. E. Code cartridge fuse) as shown in A. R. A. Fig. 26.

IVa. Wiring.

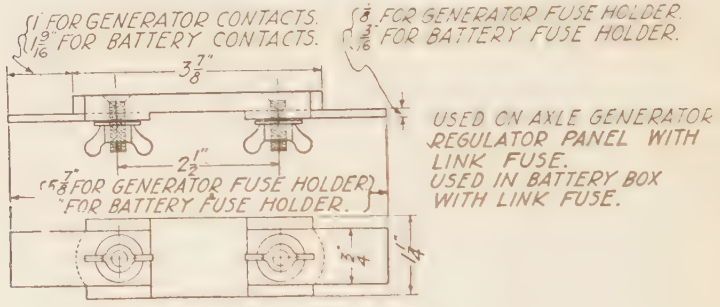
17. *Train Lines and Connectors.*—(a) Cars operated in head-end system trains shall be equipped with three train-line wires of No. 4/0 A. W. G.


USED IN BATTERY BOX FOR BATTERY:-EITHER WITH OR WITHOUT A FUSE HOLDER
2½"
OPEN END LINK FUSE. CAPACITY:- 101-200 AMPERES 250 VOLTS AND LESS.

A. R. A. Fig. 25.

(b) Cars not operated in head-end system trains may be equipped with two train-line wires of No. 2 A. W. G.

(c) All cars equipped with train lines shall have the wires terminate in train-line receptacles as shown in A. R. A. Fig. 30, and as shown in A. R. A. Fig. 28, designed so that a standard train-line connector equipped


1" FOR GENERATOR CONTACTS.
1 3/16" FOR BATTERY CONTACTS.
3 7/8"
2½"
1 5/8" FOR GENERATOR FUSE HOLDER.
FOR BATTERY FUSE HOLDER.
⅝" FOR GENERATOR FUSE HOLDER.
¾" FOR BATTERY FUSE HOLDER.
USED ON AXLE GENERATOR REGULATOR PANEL WITH LINK FUSE.
USED IN BATTERY BOX WITH LINK FUSE.

A. R. A. Fig. 26.

at each end with heads or plugs as shown in A. R. A. Figs. 28 and 29 may be used.

(d) If only two wires are used, they shall be connected to the outside terminals, and the train-line receptacle on each end of the car shall be stenciled: "NOT FOR USE ON HEAD-END SYSTEM."

(e) Where three train-line wires are used, they shall be transposed, as shown in Fig. 28.

(f) Where two train-line wires are used, they shall be transposed, as shown in Fig. 28.

(g) Train-line connections in each car shall be made across battery and generator circuit.

18. *Generator Leads.*—The electrical connections between the axle gen-

erator and permanent wiring on the car shall be made in such a manner that the leads cannot be transposed.

IVb. Lamps.

22. *Lamps.*—Standard lamps for car-lighting service shall be in accordance with the dimensions shown in A. R. A. Fig. 30.

V. Axles.

23. *Dimensions at Pulley Fit.*—The dimensions of axles used in connection with car lighting axle-driven generators shall be in accordance with A. R. A. standards.

ELECTRIC TRAIN-LIGHTING

SPECIFICATIONS FOR AXLE GENERATORS

Recommended Practice—ADOPTED, 1920; REVISED, 1922.

1. *General.*—(a) This specification is intended to cover axle generator equipment for the A. B. and C. Railroad, delivery to be made f. o. b. manufacturers' works.

(b) Submission of bid will be understood to imply that the manufacturer fully understands and accepts the requirements imposed by, and will furnish apparatus which will comply with this specification.

(c) These axle generators are intended for service on cars having a total load, lamps, fans, etc., of.....amperes at 32 volts. Each car will be equipped with.....cells of battery of.....ampere hours capacity.

NOTE: The railroad company shall specify whether the lead-acid-lead or nickel-alkali-iron battery will be used.

(d) The generator shall carry full load at.....miles per hour. (For recommended values of minimum full load speeds, see below.)

CLASS OF SERVICE.	Approximate Maximum Load Demand	Ampere Hour Capacity of Battery.		Ampere Capacity of Generator	Minimum Full Load Speed M. P. H.
		Min.	Max.		
Official, sleeping, parlor, mail and dining cars having heavy lighting loads, or severe operating conditions	50	350	600	100	26
Mail, dining cars, etc., where the lighting loads are not so heavy or the operating conditions so severe	35	300	350	75	26
Coaches, passenger-baggage cars, baggage cars under average operating conditions	25	200	300	50	21
Same cars as next above operating in slow speed branch line or local service	25	150	225	50	16

(e) The material and workmanship shall be the best of their respective kinds.

(f) The accredited representative of the A. B. and C. Railroad shall be the sole judge, on all questions that are not capable of measurement and record, as to whether or not the apparatus complies with the specification.

(g) The apparatus to be furnished shall consist of:

Axle Generator.

Axle Generator Pulley.

Generator Leads.

Generator Lead Terminal Block (to be mounted on car body).
Generator Suspension.
Generator Regulator (with corner brackets).
Lamp Voltage Regulator (with corner brackets).
Axle Pulley.
Axle Pulley Bushing.
Belt and Fasteners.
Lamp Circuit Distributing Panel.

NOTE: Any item not desired shall be crossed out.

2. *Axle Generator.*—(a) The axle generator suspension lugs shall be of such design and cross section as to eliminate, as far as possible, liability to blow holes, bubbles or other [illegible] which may tend to weaken the material in the lug or section of frame adjacent to the lug.

The holes in the lug shall not be cored. The design and location of the lug shall be approved by the railroad [illegible]. Where there is movement of suspension links or pins in the lugs the hole in the lugs shall be suitably bushed, the bushing being placed in the lug in such manner that it cannot be lost or move relative to the lug.

(b) The generator frame, pole pieces and end housings shall be machined so that all are in accurate alignment and interchangeable from one generator to another of the same make, size and type.

(c) The end housings shall be machined for the ball bearings with allowance for fit as follows:

HOUSING FITS.

Bearing No.	Outside Diameter, In.			Allowance, In.	
	Nominal.	Maximum.	Minimum.	Maximum.	Minimum.
304	2.0473	2.0473	2.0465	+.0026	+.0008
307	3.1496	3.1496	3.1488	+.0026	+.0008
308	3.5433	3.5433	3.5425	+.0026	+.0008
312	5.1181	5.1181	5.1173	+.0030	+.0012
407	3.9370	3.9370	3.9362	+.0030	+.0012
409	4.7244	4.7244	4.7236	+.0033	+.0015
412	5.9055	5.9055	5.9043	+.0037	+.0015

These allowances are based on a total tolerance of 0.0010 in. for housing bore.

(d) The armature shaft shall be annealed carbon steel having characteristics equal to or better than the following:

Carbon ..... 0.38 to 0.52 per cent.
Manganese ..... 0.40 to 0.75 per cent.
Phosphorus (not more than)..... 0.05 per cent.
Sulphur (not more than)..... 0.05 per cent.
Tensile strength, lb. per sq. in. (not less than).....80,000.
Yield Point, lb. per sq. in. (not less than) 0.5 tensile strength.
Elongation in 2 in., per cent Inverse ratio, 1,800,000 ÷ tensile strength.
Elongation in 2 in. (not less than)..... 20 per cent.
Reduction in area (not less than)..... 32 per cent.
Reduction in area, per cent Inverse ratio, 2,800,000 ÷ tensile strength.

NOTE: See A. R. A. specification for annealed carbon steel.

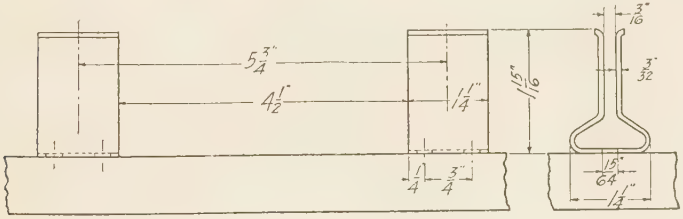
(e) The armature shaft at the fits for the inner race of the ball bearings will preferably be ground to the diameter with allowable tolerances as given below for the size of ball bearing to be used.

SHAFT FITS.

Bearing No.	Bore.			Pressed Fit Allowance, In.			Sliding Fit Allowance, In.	
	Nominal.	Maximum.	Minimum.	Maximum.	Minimum.	Desired.	Maximum.	Minimum.
304	0.7874	0 7876	0.7870	+.0011	+.0001	+.0003	—.0001	—.0011
307	1.3780	1.3782	1.3776	+ 0012	+.0002	+.0005	—.0001	—.0011
308	1.5748	1.5750	1.5744	+.0012	+.0002	+.0005	—.0001	—.0011
312	2.3622	2.3624	2.3617	+ 0015	+.0004	+.0007	—.0001	—.0012
407	1.3780	1.3782	1.3776	+.0013	+.0003	+.0006	—.0001	—.0011
409	1.7717	1.7719	1.7713	+ 0014	+.0004	+.0007	—.0001	—.0011
412	2.3622	2.3624	2.3617	+.0017	+.0006	+.0010	—.0001	—.0012

Above allowances are based on a total tolerance of 0.004 in. for draft diameter at fit.

Should the bearing be mounted on the shaft by means of an expansion device instead of a press or sliding fit, this expansion device shall be so



KNIFE BLADE CONTACT
STANDARD N.E. CODE.
CAPACITY:— 101-200 AMPERES.
250 VOLTS AND LESS.
USED IN BATTERY FUSE BOX
WITH N.E. CODE KNIFE BLADE
CARTRIDGE FUSE OR WITH
LINK FUSE AND FUSE HOLDER.

A. R. A. FIG. 27.

constructed as to relatively secure the bearing to the shaft and to lock positively under any and all service conditions.

(f) The armature shaft for all axle generators at the pulley fit shall conform to the dimensions shown in Figs. 21 or 23.

(g) The armature shaft pulley nut shall be of the ..... locking nut type. The face of the nut adjacent to the hub of the pulley shall be finished square with the axis of the thread.

(h) The armature, as a whole, shall be designed as a unit to permit the ready renewal of the shaft without disturbing any part of the winding.

(i) The commutator bars shall be hard-drawn, drop forged or cast-swedged copper with solid risers. The insulation between bars shall be

high grade mica of such design and quality as will wear at the same rate as the bars. The commutator bars shall be insulated from the shell by built-up forms of high grade mica.

The commutator shall be thoroughly seasoned and securely fastened on the shell.

The armature conductors shall be of copper, insulated, preferably with American Institute of Electrical Engineers Class "B" insulation.

(j) Bearings shall be of the annular ball type of the size specified.

Truck Suspended.		BODY SUSPENDED. Width of Belt Required to Transmit Necessary Power.									
		Free Speed						Controlled Speed			
		5 In.		4 In.		3 In.		4 In.		3 In.	
Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.	Pulley.	Comm.
412	412	412	*412	409	*409	407	*407	412	412	307	307
.....	.....	.....	‡409	.....	*409	.....	.....	.....	.....	.....	‡304

*Preferred. ‡Alternate.

Bearings shall conform to the following dimensions with the allowance and tolerance as given (S. A. E. Standards):

Bearing No.	Inside Diameter Inches.			Outside Diameter Inches.			Width Inches			Permissible Tolerances Inches	
	Nom.	Max.	Min.	Nom.	Max.	Min.	Nom.	Max.	Min.	Inner	Outer
304	0.7874	0.7876	0.7870	2.0473	2.0473	2.0465	0.5906	0.5906	0.5856	0.0000	0.0012
307	1.3780	1.3782	1.3776	3.1496	3.1496	3.1488	0.8268	0.8268	0.8218	0.0000	0.0012
308	1.5748	1.5750	1.5744	3.5433	3.5433	3.5425	0.9055	0.9055	0.9005	0.0000	0.0012
312	2.3622	2.3624	2.3617	5.1181	5.1181	5.1173	1.2205	1.2205	1.2155	0.0000	0.0016
407	1.3780	1.3782	1.3776	3.9370	3.9370	3.9362	0.9843	0.9843	0.9793	0.0000	0.0012
409	1.7717	1.7719	1.7713	4.7244	4.7244	4.7236	1.1417	1.1417	1.1367	0.0000	0.0016
412	2.3622	2.3624	2.3617	5.9055	5.9055	5.9043	1.3780	1.3780	1.3730	0.0000	0.0016

(k) One end bearing shall be mounted so that the bearing shall have approximately 0.01 in. play in the longitudinal direction of the shaft. The other end shall be mounted so that it shall have at least 1/16 in. play in the longitudinal direction of the shaft.

(l) The end housing shall have one or more circular U-shaped grooves machined in the bore through which the shaft passes; and felt washers, fitting the shaft snugly, shall be applied to the inner side of the commutator end housing and to both sides of the pulley end housing.

(m) The field coils shall be wound with copper, insulated, preferably with the Class "B" insulation of the American Institute of Electrical Engineers.

The field coils shall be form wound, impregnated with a suitable insulating compound to conform to established practices of electrical manufacturers, or thoroughly saturated by the dipping process with insulating material and then baked. The coils shall be covered with at least two layers of insulating tape laid with a half lap. The ends of each coil shall be marked to indicate the inner and outer ends of the coil. The coil shall be placed over the pole pieces and so held as to prevent positively any relative movement of the coil with respect to the pole piece.

(n) The mechanical clearance in the air gap shall be such that an oval feeler ½ in. wide and 0.05 in. thick can be passed at all points between the armature and pole faces.

(o) The pole changer shall be of such design as to throw completely, from one position to the other, in not more than ten revolutions of the armature shaft.

(p) The armature pulley shall be.....in. in diameter in accordance

with A. R. A. Drawing No.....and is intended to be driven by a ..... in. .....ply belt from an axle pulley ..... in. in diameter.

(q) Main generator and field leads shall be not less than 40 in. long and shall consist of No. 4 A. W. G. cable of not less than 61 strands, 4/64 in. wall of 30 per cent Para rubber insulation, or equivalent, covered with two braids.

(r) The generator shall be designed to generate rated voltage (40 volts) at load side of generator and to carry full load, ... amperes (net current capacity, that is, total current generated, less all field, control and regulating current used in the generator, generator regulator and lamp voltage regulator), at an armature speed not to exceed ..... r. p. m.

$$\frac{560}{60} \times \frac{\text{Diam. Axle Pulley} \times \text{Min. full load speed of car in miles per hour}}{\text{Diam. Armature Pulley}} = \text{r. p. m. of armature shaft.}$$

This value shall be known as the "minimum full load speed" in r. p. m. of the generator. (For recommended values in miles per hour see table in Section 1-d.)

(s) The generator, with an armature r. p. m. of not more than 75 per cent of the above speed, shall generate sufficient voltage and current to close the automatic switch at the voltage setting as given for same, this speed being known as the "cutting-in speed" in r. p. m.

(t) The generator shall be safe to operate both electrically and mechanically at an armature r. p. m. of

$$\frac{560}{60} \times \frac{36}{33} \times \frac{\text{Diam. Axle Pulley} \times 75 \times \text{Factor of Safety } 1.2}{\text{Diam. Armature Pulley}} = \text{max. armature r. p. m.}$$

This value shall be known as the "maximum speed" in r. p. m. of the generator.

(u) At all speeds from cutting-in to maximum speed, and at all loads from zero to full rated net ampere capacity, the generator shall operate without destructive or excessive sparking at the brushes, and the armature and armature pulley shall rotate in good mechanical balance.

(v) The generator shall be capable of delivering rated net amperes within a range of 37 to 48 volts. (This requirement is not intended to conflict with the heat test.)

3. *Suspension.*—(a) The generators shall be ..... suspended. (The Railroad Company shall insert "truck" or "body.")

(b) The suspension shall be in accordance with the following drawings of the A. B. and C. Railroad, which are hereby made a part of this specification, or they may be in accordance with the manufacturers' standard if the railroad company so elect. (List drawings or cross out section applying to same.)

4. *Belt Tension Device.*—(a) The belt tension device shall be in accordance with the following drawings of the A. B. and C. Railroad, which are hereby made a part of this specification, or they may be in accordance with the manufacturers' standard if the railroad company so elect. (List drawings or cross out section applying to same.)

5. *Generator Regulator.*—(a) The generator regulator panel shall be composed of a non-conducting, non-combustible material having a horizontal dimension of 16 in. and a thickness of at least 3/4 in.

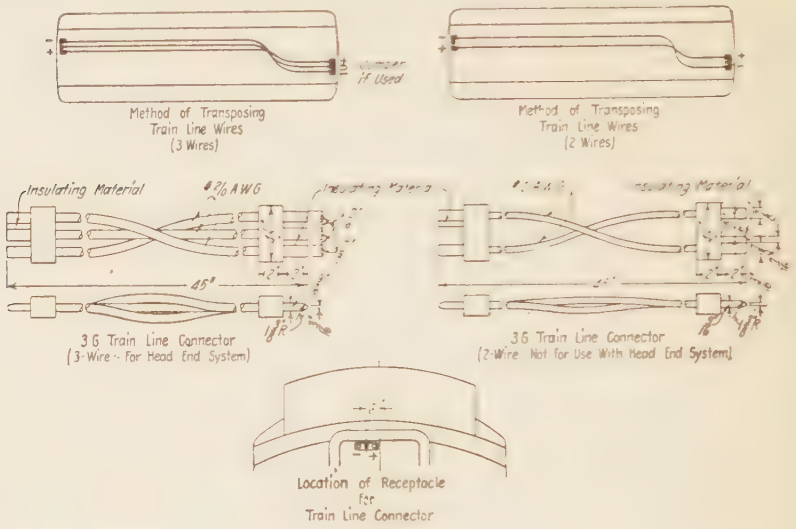
(b) The panel shall have four holes drilled in same for the supporting bolts. These holes shall be 7/16 in. in diameter and located 1 in. from the sides and 1 in. from the ends of the panel, giving a horizontal distance, center to center of these holes, of 14 in. (Should it be desired to use

a corner bracket with the panel, same shall have the supporting bolt holes drilled $\frac{7}{16}$ in. in diameter and so located that when mounted on the panel the horizontal distance between center of holes is 14 in. For attachment to the panel the corner bracket shall be drilled and tapped for a $\frac{3}{8}$-in. bolt having 16 threads per in.)

(c) The terminals on the generator regulator panel shall be arranged so that, in a horizontal direction, the positive is at the right and in a vertical direction the positive is at the top.

(d) Each terminal shall be stamped for identification and polarity.

(e) There shall be included with the generator regulator panel, wire terminals for attachment of the wires to the panel terminals; these wire terminals being stamped to correspond to the panel terminals to which they are to be connected.



A. R. A. Fig. 28.

(f) The apparatus will, preferably, be so mounted on the panel that it may be removed and reapplied without it being necessary to remove the panel from its supports.

(g) The connections between the various pieces of apparatus on the panel shall be, so far as is possible, on the back of the panel and preferably soldered after final adjustment has been made.

(h) The panel shall be supported by four $\frac{3}{8}$-in. bolts having 16 threads per inch.

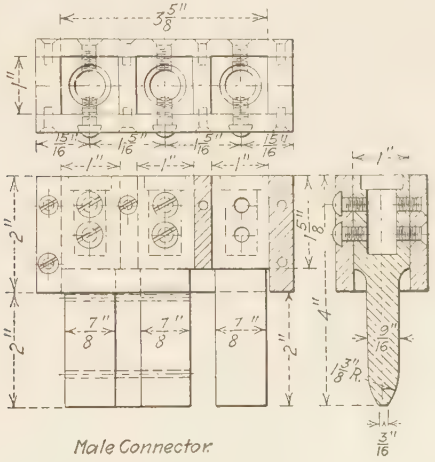
(i) Fuses, fuse contacts and fuse holders shall conform to A. R. A. Figs. 8 and 13 for fuses, A. R. A. Figs. 9, 12, and 14 for fuse contact, A. R. A. Fig. 26 for fuse holder.

(j) The generator regulator automatic switch shall be set to close at any and all operating temperatures at not more than 34 volts, this voltage being attained by the generator at not more than 75 per cent of minimum full load speed.

(k) The automatic switch must open and close without chattering, pumping, sticking, or excessive arcing.

(1) The generator regulating apparatus and battery protective devices shall be of such design as to perform satisfactorily all the following functions:

1. Close the main circuit of the generator, by means of an automatic switch, in order to permit current to flow from the generator to the battery and lamps whenever the generator develops proper voltage.
2. Open the main circuit of the generator, by means of an automatic switch, in order to prevent the discharge of the battery through the generator when the r. p. m. of the armature has decreased to a point where its voltage is less than the battery voltage.
3. Automatically prevent the overloading of the generator.
4. Automatically control the rate of charge of the battery.
5. Automatically prevent overcharging the battery either in amperes or ampere hours.
6. In case of open battery circuit the generator shall be able to carry the lamp load and the generator regulator shall automatically



A. R. A. Fig. 29.

prevent the rise in voltage upon the system exceeding 120 per cent of the rated generator voltage.

7. Means will preferably be provided whereby the adjustment of the regulator can readily be changed from the voltage and current suitable for a lead-acid-lead battery to the voltage and current suitable for a nickel-alkali-iron battery of the same ampere hour capacity, the voltage being capable of being varied independently in the latter case from 1.72 to 1.8 to 1.88 per cell to take care of temperature conditions.

8. For any given condition of battery with any variations of speed at and above 150 per cent of minimum full load speed the regulator shall maintain regulation within 5 per cent, plus or minus, of the value for which the regulator is set for operation. This value to apply equally whether the type of regulation is potential, current, watts or any combination of same.

9. When submitting proposition, the axle generator manufacturers shall describe in detail the type of control of generator output and

battery charging that they propose to furnish, submitting such curves as are necessary to afford a complete explanation.

NOTE: Railroads may substitute for section 5-1 detailed specifications covering such type or types of regulation that they desire to consider, provided that the limits are not greater than those given in this specification.

6. *Lamp Regulator.*—(a) The lamp regulator panel shall be composed of a non-conducting, non-combustible material having a horizontal overall dimension of 16 in. and a thickness of at least ¾ in.

(b) This panel shall have four holes drilled in same for the supporting bolts. These holes shall be 7/16 in. in diameter and located 1 in. from the sides and 1 in. from the ends, giving a horizontal distance, center to center of these holes, of 14 in. (Should it be desired to use corner brackets with the panels, same shall conform to the requirements as given under "Generator Regulator.")

(c) The terminals on the panels shall be so arranged that, in a horizontal direction, the positive is at the right, and in a vertical direction the positive is at the top.

(d) Each terminal shall be stamped for identification and polarity.

(e) There shall be included with the lamp regulator panel, wire terminals for attachment of the wires to the panel terminals, these wire terminals being stamped to correspond to the panel terminals to which they are to be connected.

(f) All apparatus will preferably be so mounted on the panel that it may be removed and reapplied without it being necessary to remove the panel from its supports.

(g) The connections between the various pieces of apparatus on the panel shall be, so far as is possible, on the back of the panel and, preferably, soldered after final adjustment has been made.

(h) The panel shall be supported by the four ⅜-in. bolts having 16 threads per inch.

(i) The lamp regulator shall be so designed that with the complete equipment operating in the normal manner, on bench test or in service, it will maintain the voltage across the lamp mains on the load side of the regulator under the conditions of test as specified within the following limits:

1. With the battery discharging and with the battery voltage 31 volts or less, the drop in voltage across the terminals of the lamp regulator, resistance shall not exceed 1 volt per 25 amperes flowing, for the connected lamp load.

2. With armature r. p. m. increasing at an approximately uniform rate from minimum full load speed to maximum speed in not more than five minutes and again decreasing to its original value, the voltage shall be maintained at ..... volts, plus or minus one volt at any current value not exceeding ..... amperes.

NOTE: The railroad company shall fill in the blank spaces. The recommended value for the amperes is 125 per cent of the connected load.

3. With the armature r. p. m. held constant at any given speed between the limits of minimum full load speed and maximum speed, and with the current instantaneously varied by 5 ampere steps, both increasing and decreasing, the voltage shall be maintained at ..... volts, plus or minus one volt.

4. Conditions 2 and 3 shall be complied with under any condition of charge of battery.

NOTE: Insert value at which it is desired voltage shall be maintained.

7. *Net Ampere Capacity.*—(a) The generator shall have a net ampere capacity of ..... amperes. (Net ampere capacity equals total current

generated less all current used by fields control, generator regulator and lamp regulator. For recommended values see Section 1-d.)

8. *Heat Test.*—(a) Connect the generator, generator regulator and lamp regulator (if used) in the normal manner, using rheostat or lamp bank in the battery and lamp circuits.

(b) Remove hand-hole covers and operate generator continuously for five hours at the armature r. p. m. corresponding to minimum full load speed with the generator delivering continuously ..... net amperes at 40 volts.

(c) Under the above conditions, and with temperatures measured by the thermometer method, no part shall at any time attain a temperature higher than the values given in the table.

PART OF APPARATUS.	Insulation A. I. E. E. Classification.			
	Class "A."		Class "B."	
	Maximum Observable Temperature Degrees C.	Maximum Observable Rise in Temperature Degrees C.	Maximum Observable Temperature Degrees C.	Maximum Observable Rise in Temperature Degrees C.
Any part of generator regulator, except resistance units, carbon piles, commutator, brushes, brush rigging and bare copper solenoids....	105	65	125	85
Commutator, brushes, brush rigging and bare copper solenoids.....	125	85	125	85

(d) Bearings.—Maximum observable temperature 65° C.

(e) The net ampere capacity shall be determined by the maximum net amperes that can be generated without exceeding these temperatures.

9. *Insulation Test.*—(a) Immediately after the heat test all parts of the equipment shall withstand, without breakdown, an alternating potentials of 1,000 volts, applied between conductors and ground, for a period of one minute, all metallic parts except conductors being grounded.

10. *Badge Plate.*—(a) Each generator shall have attached to it a badge plate on which the following information shall be shown:

1. Manufacturer's name.
2. Manufacturer's type and serial number.
3. Nominal voltage.
4. Rating in amperes.
5. Minimum full load speed in r. p. m.
6. Pulley ratio.

NOTE: The railroad company shall specify whether these blanks are to be filled in with the actual pulley diameter which it is intended to use or with the pulley ratio, the diameter of the armature pulley being taken as one.

11. *Rejection.*—The A. B. and C. Railroad reserves the right to reject:

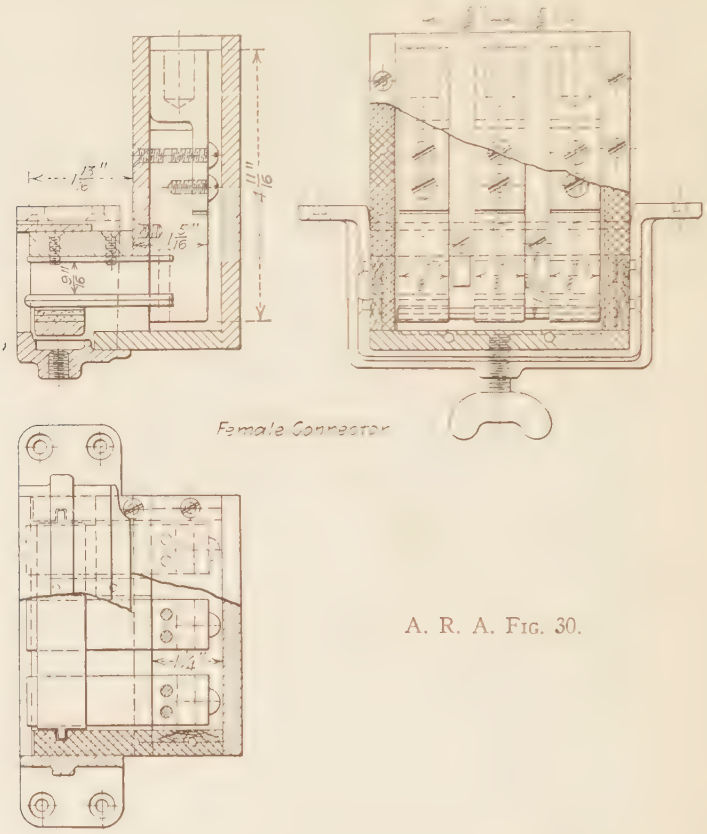
(a) Any equipment, or part thereof, that fails to comply with the requirements of the specification when inspected at time of delivery.

(b) Any equipment, or part thereof, that is defective in any way which might reasonably have been overlooked when approving the plans.

(c) Any equipment, or part thereof, that is responsible for an excessive

number of failures in service, or that is found to be defective in material or workmanship within one year of date of delivery.

12. *Patents.*—(a) The manufacturer shall insure the A. B. and C. Railroad against any and every loss arising from claim that the apparatus, as furnished, infringes patents not owned or controlled by the manufacturer and shall furnish the A. B. and C. Railroad, when requested, a satisfactory bond to cover such contingency.



A. R. A. Fig. 30.

13. *Guarantee.*—(a) The manufacturer shall correct, without charge to the A. B. and C. Railroad, any defect due to design, material or workmanship which develops within one year from date of delivery.

14. *Data.*—(a) Dimension drawings, in as full detail as may be necessary to afford thorough understanding of the equipment offered, shall be submitted to and approved by the A. B. and C. Railroad before manufacture is begun.

15. *Shipment.*—(a) No equipment shall be shipped until same has been accepted by the Railroad or inspection waived and shipment authorized.

Note: The railroad company when requesting bids shall fill in all blanks indicated thus .....

INDEX

A

Acetylene Gas 2
Alinement of Pulleys..... 58
Ammeter 169
Ampere-Hour Meter 97-126
  Types of 99
  Mercury-motor 100
  Sangamo 98, 99, 101
    Application of..... 107
Ampere-Hour Meter Chart.....120-122
Application of Graphic Meter..... 123
Armature 29, 38
Armature and Main Generator Circuit 171
Armature Rotation, Direction of... 114
Automatic Switch..... 35, 36
Axles 343
Axle Generator System..... 2, 4, 25
  Regulating Apparatus for..... 34
Axle-Driven Generator..... 4, 17, 24-60, 343, 346
  Calculating Speeds of..... 59
  Comparison of..... 55, 56

B

Battery. See Storage Batteries.
Battery and Panel Board..... 8
Battery on Charge..... 11
Battery Charge Regulation..... 34
Battery Storage Capacity..... 11
Belt Drive..... 45
Belting, Balata..... 45
Belting, Balata-Aragoma..... 45, 46
Belting, V-Shaped..... 6
Belt Fasteners..... 47, 48, 49
  Alligator Type..... 47
  Crescent Type..... 46, 47
  Jackson Type..... 48, 49
  Walker Type..... 48, 49
Belt Tension..... 49, 53, 292
Bichromate Primary..... 2
Bliss Equipment..... 5
Body-Hung Generator 53
Body-Suspension 24, 53
Booster 4
Brown-Boveri Equipment..... 4
Brushes 30
Brush Holders..... 30
Bulb Classification..... 131, 132
Buttner Equipment..... 5

C

Cadmium Test Piece..... 155
Candle Lamp..... 1
Carbon Pile..... 38, 242
Car Lighting Fixtures..... 128
  Day Coach..... 129
  Dining Cars..... 129
  Postal Cars..... 130
  Private and Business Cars..... 130
  Pullman Cars..... 129
Calculating Speed of Axle Generators 59
Ceiling Fan..... 135, 136
Charging Plug..... 326
Charge Regulation, Battery..... 34
Circuit 40, 42
Circuit Breaker..... 110
Classification of Bulbs..... 131, 132
Coal Gas..... 2
Comparison of Generators..... 55, 56
Conduit Diagram..... 128
Connecting Train Line Wires.... 20, 21
Connector 20, 348
Contacts, Carbon..... 37
Contacts, Copper..... 37
Contacts, Knife blade..... 345
Contacts, Quick-break..... 110
Control Panel..... 127, 205
Current Flow, Direction of..... 27
Current Regulation..... 34
Current Regulating Coil..... 35, 37
Cut outs 137, 139
Cutting-in Speed, to Determine..... 58

D

Dash Pots..... 35, 38, 41
D'Arsonval Instrument..... 151
Differential Shunt Feature..... 104
Direct-Drive Equipment 311
  "Bliss" Drive..... 312
  "Deutsch" Drive..... 312
  "Fitz" Drive..... 313
  "Gould" Shaft-Drive..... 313, 314
  "Gould" Chain-Drive..... 315
  "Matthews" Drive..... 316
  "Matthews-Aves" Drive..... 316
  "Pitt" Drive..... 317
  "Safety" Drive..... 317
  "U.S.L." Drive..... 318, 319
Drive, Belt..... 45
Double-throw Knife Switch..... 31

E

Electric Fans..... 136
Electric Marker Lamp..... 133
Electrolyte 158
Electro-Magnet 38, 39
E.S.B. Car Lighting System..... 191
  Armature Coil..... 183
  Body-Suspension 198
  Characteristics of..... 217
  Control Panel..... 205
  Generator 191, 237, 294, 323, 335
  Generator Regulator.... 195, 219, 255 295, 306
  Generator Regulator Panel..... 194
  Storage Battery..... 214, 307
  Truck Type Suspension.. 198, 199, 244
Exide Storage Battery..... 91, 92
  Box Negative Group..... 93
  Grids are Assembled..... 92
  Manchester Button..... 93
  Manchester Positive Plate..... 91, 93
  Wood Separator..... 93

F

Fan, Ceiling, Electric..... 135, 136
Female Connector..... 20
Field Carbon Pile..... 35, 37
Field Coils and Retainers..... 29
Field Circuit May Be Traced..... 172
Field Fuse..... 35
Fixtures. See Car Lighting Fixtures.
Flow of Current..... 44
Floor Plan of Generator Testing Room 163
Fuse 328

G

Gas Lamp..... 2
Gasoline 3
Generator 3
Generators, Comparison of..... 55, 56
Generator Fuse..... 35, 40
Generator Regulator..... 34, 3
Generator Suspension..... 50
Gibbs Connector..... 19
Gould & Newbold Equipment..... 5
Gould "Simplex" System..... 215-235
Adjusting the Automatic Switch 233, 303
Adjustment of Generator Regulator 231
Automatic Switch..... 219
Axle Generator..... 216
Earlier Types of..... 235
Field Rheostat or Carbon Pile.... 220
Generator Regulator and Lamp Controller 222
Generator Suspension.....226, 291
Lamp Regulator..... 224
Adjusting Type M-2..... 233
Operation of..... 229
Lamp Regulator Panel..... 226
Link Type Four-Point Bearing Truck-Suspension 228
Operation 226, 307
Ground Test..... 171

H

Head-End System..... 2, 17
Arrangement of..... 21
History of Car Lighting..... 1
Housing Fits..... 344
Housing Heads..... 2
Hydrometer 16

I

Incandescent Lamps..... 6
Increasing Light Load Accuracy.... 106
Iron Core..... 36
Installing Conduit..... 143
Installing Panels..... 147
Wiring 143
Wiring of Regulator Panels..... 146
Installing Equipment..... 140
Material 141
Locating Battery Box and Cabinet. 141
Placing the Car on Trestles..... 141
Inspecting an Armature Circuit..... 172
Internal Battery Losses, Compensation of..... 106

L

Lamps 2, 131, 343
See also Train-Lighting Lamps.
Lamp Carbon Pile..... 39
Lamp Circuit..... 2, 40
Lamp Regulator..... 34, 39
Lamp Equipment..... 5
Lever Arms..... 35
Life of a Generator Belt..... 57
Lifting Coil..... 36
Lifting Coil Resistance Unit..... 35
Lighting Circuits..... 127
Lining up the Generator..... 52, 54
Lining-up Suspension Bracket..... 149
Load Accuracy, Increasing..... 106
Locating Trouble on a Car Lighting Equipment 173
Losses, Battery..... 106
Lost Motion of Running Gears..... 57
"Lumen" 132

M

Magneto 169
Magnet Core 28
Magnet Frame..... 28
Magnetic Flux..... 36
Magnetic Pull 36
Maintenance 50
Male Connector 46
Male Gibbs Connector 20
Manchester Plate..... 91, 93
Mantle Lamp 2
Manuel Reset 346
Mather-Platt Equipment 5
Mazda B..... 131
Mazda C..... 131
McElroy Equipment..... 5
Meter, Ampere-Hour..... 97-101, 113
Method of Testing Generator..... 163
Morris-Moskowitz Equipment..... 5
Motoring Test..... 171

N

Negative Plates. See Plates.
Negative Plates, Box Group..... 93
Newbold Equipment..... 5
Nickel-Iron 63
Nickel-Oxide 88
Normal Charge..... 90

O

Oil Lamp..... 1
Open Circuit..... 172, 176, 179
Overcharge Feature..... 102
Oxide, Iron..... 88
Oxide, Nickel..... 88

P

Pintsch Gas..... 2
Pintsch-Grob Equipment..... 4
Placing Spring in Bracket..... 150
Planté Type of Battery..... 2
Plates, Negative. See Storage Batteries.
Plates, Positive. See Storage Batteries.
Plungers 35
Poles 29
Polarity of the Armature..... 114
Polarity of the Field..... 114
Pole Changer..... 28, 30, 32, 239, 295
Rotating Type..... 30
Mechanically Operated Switch Type 31
Plug Cut-out..... 139
Pulleys 46, 332-341
Putnam Storage Battery..... 93
Connections 96
Plate Construction..... 94
Planté Type..... 94
Positive Element..... 95

R

Receptacle 20, 324
Regulating Apparatus..... 34-44
Regulating Coil..... 40
Regulator Panel..... 35
Regulator Parts..... 35
Removing Generator from Car..... 162
Resistance Unit..... 38, 41
Rheostat 220
Rosenberg Equipment..... 4
Rotation, Clockwise..... 33
Rotation, Counter-Clockwise..... 33
Rotation, Direction of..... 27

S

Safety Car Lighting Equipment.. 5, 237
Armature 242
Carbon Pile..... 242
Dash Pot..... 242
Dynamo Regulator, Type FF.... 239
Electro-Magnet 242
Field Coil Connections..... 253
Generator Voltage Regulating Coil 263
Lamp Regulator..... 243, 257, 263
Magnet Coil..... 242
Operation of Lamp Regulator.... 251
Pole Changer..... 239, 295
Resistance Unit..... 242
Safety F-1 Regulator..... 253
Safety FR Equipment..... 253
Slate Panel..... 242
Special Generator for Pullman Equipment 264
Special Type F for Pullman Company 266
Terminal Posts..... 242
Type F Lamp Regulator..... 242
Type F-2 Safety Generator..... 252, 254, 258
Underframe Suspension..... 247
Sangamo Ampere-Hour Meter... 99-107
Sangamo Circuit Breaker..... 110
Sangamo Control Panel..... 12
Screw Contact..... 328
Series Coil..... 36, 40
Service Inspection and Testing..... 169
Shaft Fits..... 345
Simplex System. See Gould.
Size of Pulleys..... 57
See also A. R. A. Specifications.
Slate Panel..... 35, 38 242
Slipping Belt for Regulation..... 4
Specific Gravity, Storage Battery... 159
Springs 35
Straight-Storage System..... 2, 7, 15
Steam-Driven Generators 3, 4
Steam Turbine..... 3
Stone-Franklin Car Lighting Equipment 5, 267
Application of..... 273
Automatic Panel..... 270, 271
Battery Control..... 273
Belting 277
Change-over Switch..... 277
Generator, Type T-35..... 268
Operating Features..... 271
Operating with Sulphated Battery. 273
Lamp Voltage Regulator..... 274
Reducer Switch..... 274, 275
Relay Switch 274, 277
Stop-Charge Feature 106
Storage Batteries..... 61-96, 322-329
Action of Discharge..... 71
Action of Charge..... 71
Active Materials of a Lead Cell.. 71
Storage Batteries (*Continued*)
Ampere-Hour Capacity 77
Alkaline Storage Cell..... 80
Camila A. Faure..... 61
Charles H. Brush..... 61
Containing Vessels..... 63
Charge and Discharge Curves.... 73
Corrosion 76
Connectors 84
Chemical Reactions..... 87, 88
Capacity and Charging Rates..... 91
Complete Cycle..... 89
Elements in the Lead-lead Cell... 69
Electrolyte 70, 84
Electro-Motive Force..... 73
Edison Battery, Theory..... 85
Fundamental Principle of..... 88
Faraday 61
Gautherot 61
Iron Oxide..... 88
Lead-Lead Type 62, 63
Lead Lining..... 65, 66
Lead Cover 65
Limit of Discharge..... 73
Maintaining the Capacity..... 77
Method of Forming the Plates..... 67
Nickel-Iron 63
Negative Plates..... 69, 83, 92
Negative Plates, Reaction of..... 71
Negative Plates, Bring up to Capacity
Negative Pocket..... 81
Nickel-Oxide 88
Normal Charge and Discharge Voltage Curves..... 90
Porcelain Rests..... 65
Planté 61
Plates, Positive and Negative.. 65, 68
Positive Plates..... 82
Positive Tubes..... 81
Positive Plate, Reaction at..... 71
Reason for the Growth of Plates.. 75
Rubber Jar..... 63
Specific Gravity..... 84
Sediment 74
Separator 63, 69
Separators-insulation 84
Shedding of Active Material..... 74
Sinsteden 61
Slatted Crate..... 66
Theory of a Lead-Lead Storage Battery 70
Thomas A. Edison..... 61
Trays 84
Use of in America..... 3
Variation of Capacity..... 75
Voltage at Terminals..... 73
Switches 137, 138
Change-over 277
Double-Throw 31
Knife Switch..... 138
Push Button Switch..... 138
Reducer 274, 275
Relay 274, 277
Snap Switch..... 137

T

Tension Spring 53, 54
Terminal Posts..... 35, 38
Testing and Adjusting..... 151
Testing and Connecting..... 179
Testing for "grounds," "short," and "open"..... 176
Test Lamp..... 169
Testing a Nickel-iron Battery.... 161
To Locate a "ground" or "open" 172, 179
To Locate "short"..... 176

Three-Wire Train Line..... 18
Tools for Handling Car Lighting Equipment 181-190
Armature Hand Press..... 183
Armature, Removing and Applying 181
Armature Shaft and Bearing, Press for Removing..... 182
Armature Shaft, To Remove from the Armature..... 183
Axle Generator Belts, Applying and Removing 184
Battery Covers, Removing and Applying 188
Block for Supporting Armature... 182
Emergency Welding..... 188
Lead Battery Plates, Press for... 187
Lifting Irons for Edison Batteries 190
Lining-up Axle with Body-Suspended Generator..... 186
Protecting Armature and Commutator 181
Pulley and Bearing Puller..... 185
Pulley Lifting Iron..... 185
Steam Caps for Removing Battery Covers 188
Wire Connectors for Batteries.... 188
Train Lighting Lamps..... 131
Bulb Classification..... 131, 132
Electric Marker..... 133
"Lumen" 132
Mazda B..... 131
Mazda C..... 131
Unit-solid Angle 133
Train Line..... 17
Train Line Connectors..... 19
Train Line Wires..... 19
Transmission 45
Transmission Graph..... 58
Truck Suspension..... 24, 50, 51

U

Under-Car Work..... 149
Unit-solid Angle..... 133
U.S.L. Car Lighting Equipment..... 281
Adjusting Generator Regulator... 303
Ampere-Hour Meter..... 289
Belt Tension Device..... 292
Constant Belt Tension..... 292
Generator Regulator Panel, Type C 303
Testing and Adjusting, Type C. 304
Generator, Type A.....282, 283
Lamp Regulator, Type B..... 298
Testing, Type B..... 303
Lamp Regulator..... 288, 299, 350
Operation of..... 285, 300
Regulator Panel..... 284
Type A Equipment..... 281
Type C Equipment..... 294
Voltage Coils..... 289
U.S.L. Equipment—P.R.R. Specifications 305

V

V-Faced Pulleys..... 6
V-Shaped Leather Belting..... 6
Variable Resistor Element..... 103
Vicarino and Dick Equipments..... 4
Voltage Coil Resistance Unit..... 35
Voltage Reading, Battery..... 176
Voltage Reading, Cell..... 174
Voltage Regulating Coil.... 35, 57, 289
Voltmeter 169

W

Wire. See A.R.A. Specifications
Wires, Train Line... 17, 19, 20, 21, 348
Wiring. See A.R.A. Specifications

APPENDIX

American Railway Association—Standards and Recommended Practices 321-352
Axles 343
Axle Generators, Specifications for.. 343
Body-Suspended 346
Axle Generator Fuse Clip..... 329
Batteries, Storage..... 322, 323, 341
Assembled in Trays..... 322
Charging Plug..... 326
Charging Receptacle Case..... 324
Method of Connecting Set To Car Wiring 322
Ventilation of..... 327
Wiring 325, 352
Cartridge 330
Clip Contact..... 329
Descriptive Notices, A.R.A..... 331
Edison Screw Contact..... 328
Edison Screw Plug..... 328
Female Connector..... 352
Ferrule Contact..... 330
Guarantee, A.R.A..... 352
Generator Leads..... 342
Housing Fits..... 344
Heat Test..... 351
Insulation Test..... 351
Joints and Splices..... 330
Knife Blade Contact..... 345
Lamps 343
Male Connector 352
Net Ampere Capacity..... 350
Open-End Link..... 328
Patents 352
Pulley, Generator, 4½ in..... 332
Pulley, Generator, 5½ in..... 333, 334
Pulley for Free-Speed Generator, 6½ in..... 336
Pulley for Free-Speed Generator, 8 in..... 337
Pulley for Free-Speed Generator, 10 in..... 338
Pulley for Free-Speed Sleeve Bearing Generator 339
Pulley Hub..... 340, 341
Receptacle 351
Screw Contact..... 328
Shaft Fits..... 345
Train Lines and Connectors..... 342
Train Line Wires, Method of Transposing 348
Truck-Suspended Generator..... 346
Type of Fuse..... 328
Wire 330

625.22 S92C

a39001 007360988b